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SEMI-ANNUAL PROGRAM PROGRESS REPORT FOR THE TERMINAL RADIATION PROGRAM (TRAP)

UNCLASSIFIED VOLUME

M. H. Smotrich
TRAP Program Manager

AVCO EVERETT RESEARCH LABORATORY

For The Period 1 January - 30 June 1967

prepared for

SPACE AND MISSILE SYSTEMS ORGANIZATION
DEPUTY FOR BALLISTIC MISSILE RE-ENTRY SYSTEMS
AIR FORCE SYSTEMS COMMAND
Norton Air Force Base, California

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Contracts No. AF 04(694)-865
and F04694-67-C-0047

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FOREWORD

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This report summarizes the progress and status of work performed by the Avco Everett Research Laboratory for the Terminal Radiation Program (TRAP) during the six-month period January 1 through June 30, 1967. This work was performed under Contracts AF 04(694)-865 and F04694-67-C-0047 for Space and Missile Systems Organization, Air Force Systems Command, Deputy for Ballistic Missile Re-entry Systems, Norton Air Force Base, California. The Air Force program monitor for these contracts is Captain Robert L. Aspinwall, SMYT.

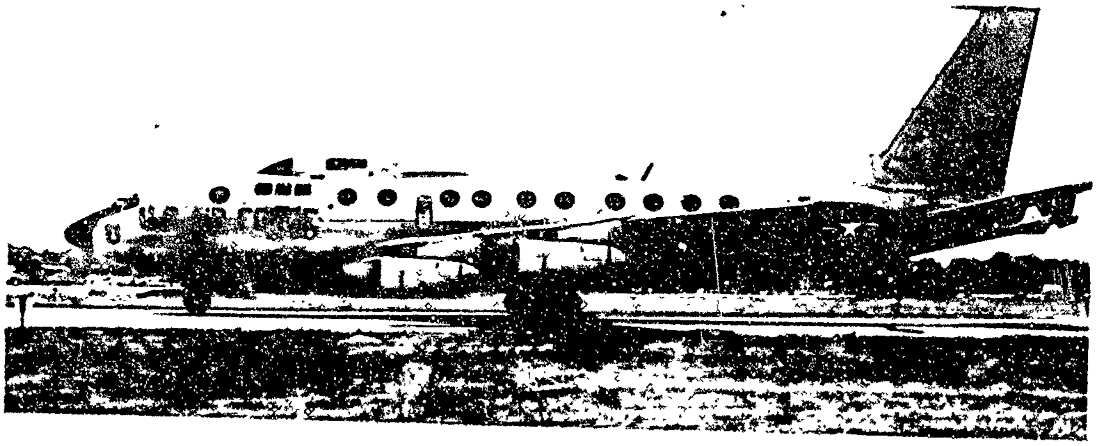
Activities are reported in this volume for those tasks which can be described in an unclassified manner. Task titles are the same as those used in the Statements of Work for the two contracts.

Publication of this report does not constitute Air Force approval of the report's findings or conclusions; it is published only for th- exchange and stimulation of ideas.

Captain R. L. Aspinwall
SMYT

ABSTRACT

A narrative summary is given of the progress and status of six months' work performed by Avco Everett Research Laboratory for the Terminal Radiation Program (TRAP). The period covered is January 1, 1967 through June 30, 1967. Efforts are described for those tasks which can be discussed in an unclassified manner, and include program management, operations, instrumentation and maintenance, calibration and system studies. These tasks are discussed for the TRAP-6 and TRAP-7 re-entry monitoring aircraft and the TRAP-Transportable ground station. In addition, work pertaining to the upgrading of the TRAP-1 aircraft is described.



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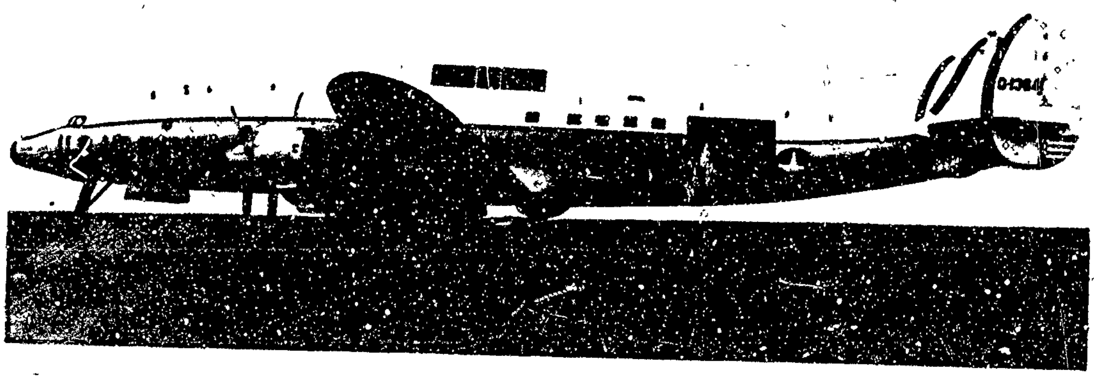

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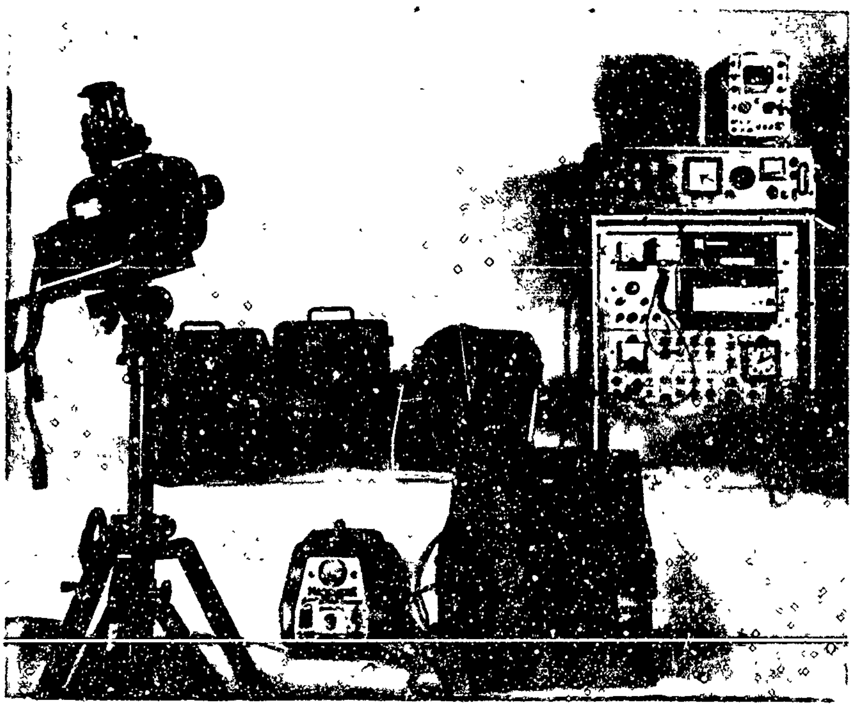

TRAP - TRANSPORTABLE

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INTRODUCTION

This Semi-Annual Program Progress Report is a combined progress report for both the contracts held by Avco Everett Research Laboratory which together encompass the TRAP program. Contract AF 04(694)-865 pertains to the TRAP-1, TRAP-6 and TRAP-Transportable programs, while Contract F04694-67-C-0047 pertains to the TRAP-7 program. These contracts emcompass the operations and data gathering, data reduction, studies, and reporting aspects of the optical re-entry data collected by the specially outfitted aircraft designated as the TRAP-1 (KC-135), the TRAP-6 (JC-121C), TRAP-Transportable (a specially deployed ground system), and the TRAP-7 (KC-135). The reporting period is January 1 through June 30, 1967; the TRAP-7 contract for Avco Everett commenced on February 1, and progress is reported from that date through the end of June.

For convenience of handling, this combined report has been divided into two volumes: an unclassified, and a classified volume. In each volume, the appropriate tasks for each contract are included. The basic division of volumes and sections is as follows:

UNCLASSIFIED VOLUME

SECTION I: Contract AF 04(694)-865

Task 1.0 Program Management

Task 4.0 System Studies

Task 5.0 Instrumentation, Maintenance and Service

Task 6.0 Operations and Measurements

Task 8.0 TRAP-1 Upgrade

SECTION II: Contract F04694-67-C-0047

Task 1.0 Management

Task 2.0 Operations and Measurements

Subtask 4.2 System Improvement

Task 5.0 Calibration and Test

CLASSIFIED VOLUME

SECTION III: Contract AF 04(694)-865

Task 2.0 Interpretation and Correlation of Data

Task 3.0 Data Processing and Reduction

Task 7.0 Data Management/STINFO Program

SECTION IV: Contract F04694-67-C-0047

Task 3.0 Data Reduction and Analysis

Subtask 4.1 R/V Modification, To Enhance Optical Acquisition and Interpretation

Task 6.0 Data Interpretation

Task 7.0 Data Management/STINFO Program

Activities under the AF 04(694)-865 contract have continued at an ever increasing pace with significant progress accomplished in all Tasks. The TRAP Program Office was realigned and expanded to better direct and control the data gathering platforms and primary areas of functional importance. Task 1.0 also summarizes the efforts associated with Avco Everett's response to a CCN to the basic contract as well as an RFQ for the TRAP-6 and TRAP-Transportable platforms. In the area of Data Interpretation and Correlation, Task 2.0, is presented a summary of the progress accomplished in the areas of vehicle stability, vehicle demise, wake turbulence, boundary layer radiation, etc. At this writing, the efforts under all of these Special Study Subtasks is nearing completion. Task 3.0, Data Processing and Reduction, which also includes the area of instrument calibration under this contract, highlights the acquisition and implementation of new instrumentation in the areas of processing and analysis, a statistical approach towards establishing the accuracy of various instrument calibration and a summary of a recent evaluation of the photometric calibration unit utilized on the TRAP-6 aircraft.

In the area of System Studies, Task 4.0, progress is presented for a new instrument, an atomic line radiometer, and a Fabry-Perot Etalon instrument concept. Also included is a summary of a recently completed report on instrument calibration. Summarized in Task 5.0, Instrumentation, Maintenance and Service, is a compilation of the major maintenance items

accomplished during this period as well as the progress in the acquisition of a VIS/IR radiometer and a concept for automated microdensitometry. Task 6. 0, Operations and Measurements, presents a summary of activities in the area of field operations and support and Task 7. 0, Data Management, a summar, of data reports and highlights for reports issued during the period.

The major aspect of the TRAP-7 contract was that Avco Everett assumed responsibility for the TRAP-7 instrumentation system on February 1, and that both the operational and data aspects of the contract were successfully implemented on a very short time scale. Task 1. 0, Management, summarizes program accomplishments for the period, for all tasks. Task 2. 0, Operations and Measurements, including System Maintenance, summarizes the takeover period and the experience gained in maintaining and operating the TRAP-7 system throughout the period. Task 3. 0, Data Reduction, includes highlights of data reduced, and a discussion of techniques employed in reduction. Task 4. 0, System Studies, includes a discussion on R/V modification to enhance optical acquisition in the classified volume, and a summary of system upgrading considerations in the unclassified volume. Task 5. 0, Calibration, summarizes a comprehensive evaluation of the on-board calibration unit. Task 6. 0, Data Interpretation, includes R/V diagnostics of TRAP-7 data collected during the period, some of which were incorporated into -865 studies for unified subject treatment. Task 7. 0 documents the data reports and TRAP Memoranda issued during the period.

CONTRACT AF 04(694)-865

(TRAPs-1, -6 and - T)

UNCLASSIFIED TASKS

SECTION I

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TASK 1.0 PROGRAM MANAGEMENT

J. E. Nunes

This reporting period has been one of the most active in the history of the AERL TRAP Program. Concurrent activities have transpired in the areas of the takeover and operation of the TRAP-7 aircraft, presented under the -047 portion of this report, planning associated with the upgrading of the TRAP-1 aircraft under a CCN to the - 865 contract, reprogramming other areas of the contract impacted by the CCN (the TRAP-Transportable ground station, an extension of the Data Processing and Reduction task and the incorporation of a 5µ wake scanning radiometer), as well as the general efforts of a continuing nature under the basic Program.

Early in the year, so as to keep pace with and properly direct the expanding requirements of the Program, the TRAP Program Office was significantly enlarged to add emphasis to the monitoring platforms and primary areas of contractual importance. Program Managers were designated for each of the major platforms as follows: Mr. P. Howes, TRAP-1; Mr. J. Nunes, TRAP-6 and Transportable; and Mr. R. Radle, TRAP-7. These Program Managers have the end responsibility for the performance of each platform across all tasks and report directly to the TRAP Program Director, Dr. M. H. Smotrich. The contractually aligned responsibilities such as Operations, Instrumentation, DP&R, etc, were established so as to add support and continuity across all platforms where such commonality of approach is allowed by the respective contracts. The chart showing the organization of the AERL TRAP Program Office is presented as figure I-1.

A vast amount of planning has been associated with the reconfiguration of the TRAP-1 aircraft. This KC-135 was delivered to Martin-Morietta Co. in February where it is undergoing modification for the addition of eleven optical windows behind which will be positioned, when the final phase of the upgrading is complete, an extensive compliment of gimbal-mounted payloads.

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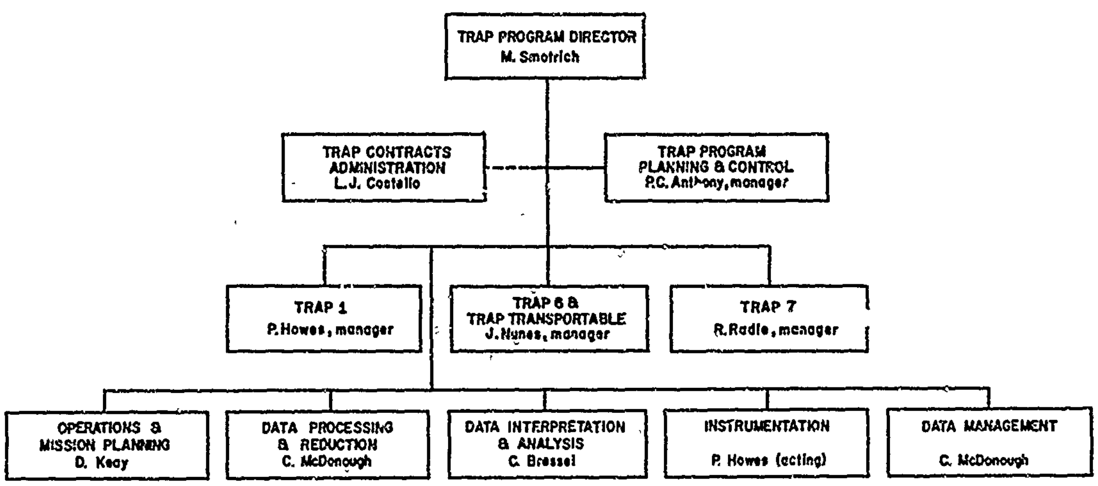


Fig. I-1 TRAP Program Office Organization.

Following aircraft modification an IRAN will transpire, and present plans call for aircraft return to Wright Patterson AFB in September when installation of an interim configuration of equipments will begin.

After receipt of CCN #1 to the -865 contract in April, a Program Plan was prepared and submitted to SAMSO for approval. This Plan presented AERL's management and technical approach to those areas covered by the CCN, heretofore mentioned.

Also in preparation, in parallel with the Program Plan, was a Preliminary Design Report covering, in detail, the configuration and specifications of equipments proposed for utilization on the TRAP-1 aircraft in both the interim and final (upgraded) configurations. This PDR was subsequently submitted in June. It should be noted that a summary of the effort associated with the upgrading of TRAP-1 is presented in Task 8.0 of this report.

In June, an RFP was received from SAMSO for the follow-on contractual efforts under the TRAP-6 and TRAP-Transportable Programs. In response, a Program Plan and Cost Proposal were prepared and submitted in July which presented our approach to and plans for these Programs for the eighteen-month period from 1 October 1967. Negotiations are expected to be scheduled sometime during the month of October. It is noteworthy to mention here that these latter two platforms as well as the TRAP-1 aircraft are presently supported by the - 865 contract whereas in October TRAP-6 and TRAP-Transportable will be split off and supported under SAMSO Contract F 04 694-67-C-0130.

Significant progress has been made in many tasks during this 6-month period. Of particular note is the Special Studies area, Task 2.0, presented in the classified volume of this report and System Studies, presented herein. Two new instruments are nearing completion, an atomic line radiometer and a VIS/IR radiometer, and these are discussed in Tasks 4.0 and 5.0 respectively. With the TRAP-1 aircraft undergoing modification during the majority of this 6-month period, the demands for mission support from the TRAP-6 aircraft and TRAP-Transportable ground station have significantly increased and they have been called upon to perform monitoring activities on all three of the National Test Ranges, frequently on an extremely accelerated schedule.

In conclusion, this reporting period has been one of expansion and accelerating program requirements. Every effort has and will continue to be put forth in providing SAMSO and the re-entry community with all the TRAP support necessary in this area vital to the National Defense.

TASK 4.0 SYSTEM STUDIES

J. E. Nunes

Introduction

The area of system improvement studies has been especially active during this period and has resulted in the completion of two studies and partial fulfillment of one other. A fourth study relating to the upgraded TRAP-1 pointing system is considered fulfilled by the effort in that area, a summary of which is part of Task 8.0 of this Report.

The completed Atomic Line Radiometer study is summarized within this section and the instrument itself is nearing vendor completion. This study presents the theory and design concepts from which instrument development was initiated.

A system study on instrument calibration was also completed, and an abstract of the report is contained herein. Calibration equipment recommendations resulting from this study are also included.

Two areas of effort comprise the High Spectral Resolution study. Of these, one has been completed by the submission to SAMSO, of a preliminary design memoranda on a high spectral resolution Fabry-Perot etalon instrument and is summarized herein. The final report in the second category will be issued in the near future and cover grating type instruments. With the publication of this report, the effort on this study will be completed. Additionally, a preliminary design memorandum on an Image Intensifier Cinespectrograph and Image Intensifier Acquisition Sight has been prepared and forwarded to SAMSO for approval. These latter instruments were not initially included as completion items under this Task. A summary of this memorandum is also included in this section.

Study efforts are continuing in the areas of High Resolution System Evaluation and the TRAP-6 Pointing System. The former study will result in a report on the evaluation of the 80" focal length instrument in use on the TRAP-6 aircraft since late 1966 and the latter, a report on the evaluation of the pointing/gimbal system also in use on the aircraft since that time. A summary of the status of both studies is presented.

It should be noted that of the efforts presented herein, those which have titles preceded by a numerical designation represent contract completion items.

4.2.1 High Resolution System Evaluation (J. E. Nunes)

In the last Semi-Annual Report, an evaluation of the 80" focal length Cassegranian type objective designed for use in obtaining high spacial resolution measurements from the TRAP-6 aircraft was presented. Since that evaluation, further progress has been made in refining the theoretical constraints of the Jones design, and while not presented herein, this will be included in the final evaluation report.

An outline for this report has been prepared. It is anticipated that five distinct categories will be required to adequately provide the depth necessary for the evaluation. They are as follows:

I - System Description: This section will contain a description of the 80" FL high resolution system as installed on the TRAP-6 aircraft.

II - Optical Evaluation: An evaluation of the design of the Jones Cassegranian system and the results of bench tests performed on the TRAP-6 and equivalent lens systems. Also included will be a comprehensive analysis of all optical system characteristics noted to date.

III - System Evaluation: This section will contain a presentation and analysis of existing data in terms of optical quality (smear, definition, resolution, exposure, etc.). The effects of the camera and gimbal/pointing system will be introduced and discussed. Comparisons, as applicable, will be made with a similar high resolution system in use by AERL on another program.

IV - Window Effects: The possible effects which aircraft windows have on the quality of high resolution data will be discussed.

V - Conclusions and Recommendations: The data and analyses as presented in Parts II, III and IV will be discussed with respect to overall present and future usefulness to the TRAP Program. Problem areas and system limitations will be presented. These

areas in which it is felt that further performance improvements are possible within the framework of the existing system will be presented.

Several samples of data have been recorded by this instrument to date. On one mission, WSMR #72, vehicle transition was documented, and this sequence is shown in Task 3.0 of this Report. Data obtained after this latter mission was examined and found to contain double images causing a recall of the instrument to AERL. An examination of the telescope indicated optical misalignment and the instrument was realigned and returned to the TRAP-6 aircraft.

Although some of the data obtained by the instrument has not been optimum, e.g., that taken just prior to its return for realignment, it is still quite useful in evaluating instrument design and overall performance in an airborne environment.

4.3.1 An Atomic Line Radiometer (R. Prescott)

Introduction

Many types of ablating heat shields for re-entry missiles become incandescent during re-entry with peak temperatures of the order of 3000°K and radiation in the visible of intensities of the order of megawatts per steradian. In the presence of this intense radiation, it is of interest to measure much lower levels of radiation due to atomic lines. Moderate success has been achieved in the past by the use of relatively high linear dispersion grating spectrographs to disperse the continuum so that a relatively low level atomic spectral line would be detectable above it in a photographic recording spectrograph. Attempts to use narrow band filters have resulted in ambiguous data only; it was impossible to determine the level of interference due to the background continuum.

Several instrumentation concepts have been evaluated in a search for a method with suitable sensitivity and lack of ambiguity.

The scheme embodied in the present instrument is a concept which grafts a proven method of measuring atomic lines against the night sky with the proven radiometric methods evolved in re-entry monitoring. It provides a simultaneous measure of the atomic line intensity, the intensity of the

continuum, and the level of sky background in the spectral region of the atomic line. It provides suppression of sky background by means of spatial filtering and of missile continuum radiation by means of spectral filtering.

Resolution

If a spectrograph is used to measure an atomic line against a continuum background, then it is useful to estimate the threshold or level at which the line can be detected against a given continuum level as the continuum level multiplied by the spectral resolution of the instrument. For instance, if a spectrograph had a resolution of 10 A and a threshold of 10^{-10} watts/cm^2 - micron, then the threshold for an atomic line would be $\sim 10^{-13}$watts/cm^2 with no continuum and $\sim 10^{-3}$ of the continuum level in any case within the dynamic range of the instrument.

Background Consideration

Background may be considered to be primarily airglow, both continuum and spectral lines, and stars. From another point of view, the continuum radiation from the missile in the spectral region of interest may be considered background but, as it is measured and these measurements are useful data, it is quite different from the sky background.

Figure I- 2 is adapted from a figure in Chapman and Carpenter[1] and shows the level of spatially continuous night airglow. It shows that a significant level exists on a moonless night even after astronomical twilight. In the region of the Milky Way, the level is significantly higher as it is also when the moon is above the horizon.

Instrument Concept

The instrument concept is a combination of the well known birefringent polarizing filter devised by Lyot[2] as adapted to the measurement of atomic lines in the night airglow[3] with the principles of radiometry developed here using simple spatial filters.

The heart of the instrument may be understood by referring to figure I-3 (adapted from Ref. 3) in which is shown a schematic of the birefringent filter. Collimated light is polarized by the first Polaroid. It then passes into the quartz crystal whose optical axis is parallel to the surface and at 45° from the Polaroid axis. It is broken into two equal components which

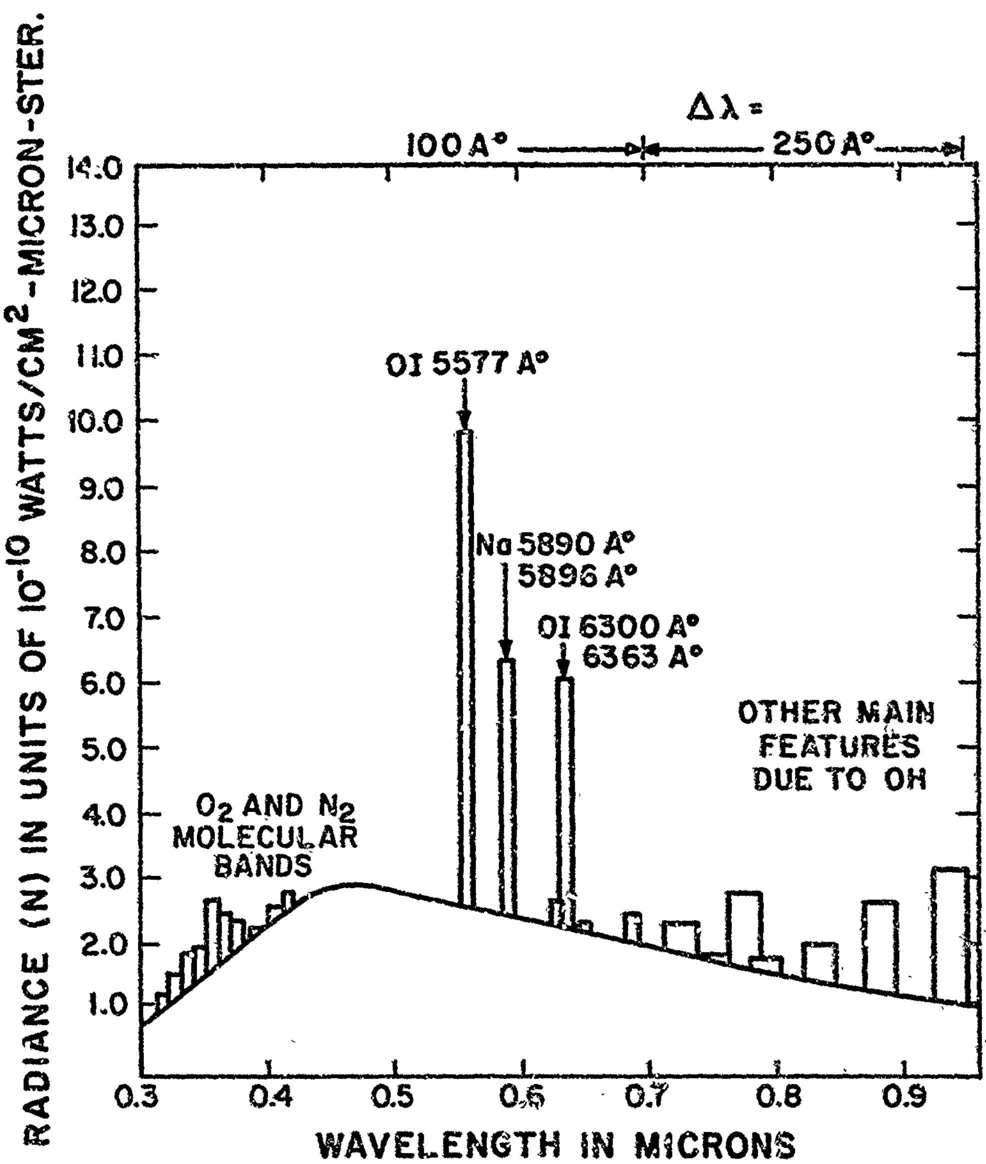


Fig. I-2 Sky background radiance vs. wavelength.

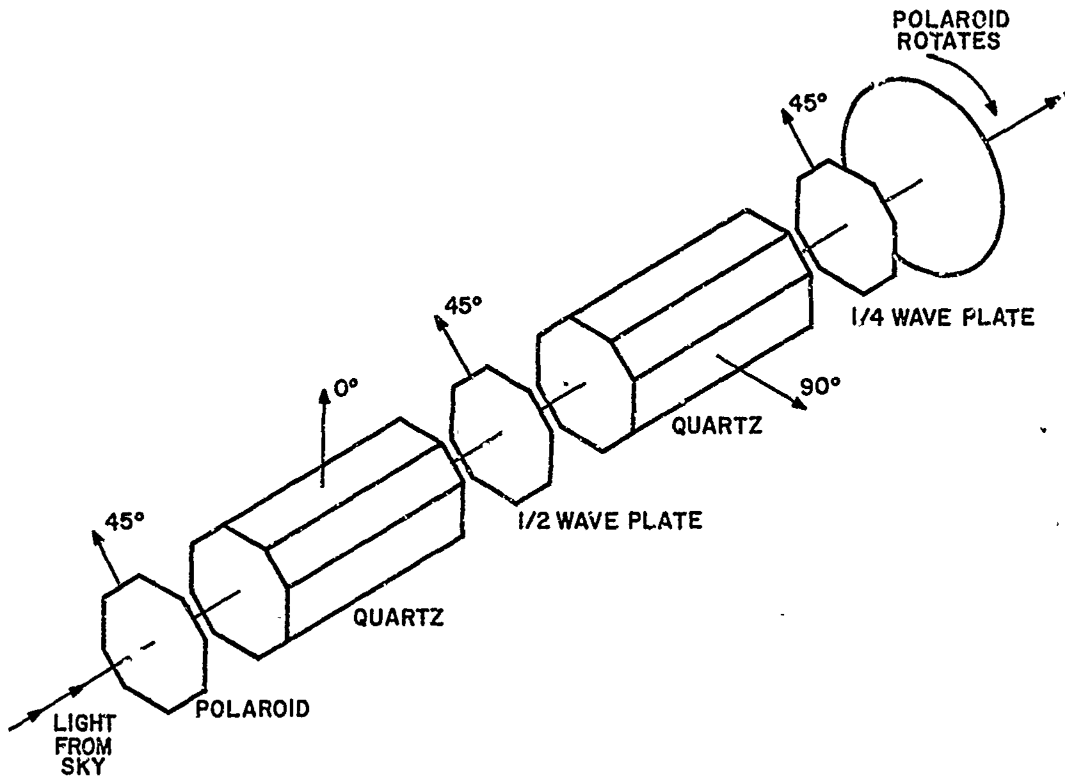


Fig. I-3 An exploded view of the birefringent filter.

travel through the quartz at different velocities. As the waves emerge from the first quartz block, they pass through a half-wave plate whose fast or slow axis is parallel to the axis of the Polaroid. This causes the fast and slow waves to be effectively rotated through 90°. The second block of quartz has its slow axis at 90° from the same axis of the first quartz block. In passing through this plate, the slow wave is further retarded. The purpose of accomplishing the retardation in two steps with the slow axes at 90° from each other is to reduce the change in retardation for waves which are not parallel to the optical axis, so that the lack of perfect collimation does not reduce the effectiveness of the instrument. On emerging from the second block of quartz, the wave passes through a quarterwave plate whose axis is 45° from that of the quartz block, so that the light is now rendered plane polarized with an angular orientation which is a function of its wavelength. A rotating Polaroid placed behind this block will modulate each monochromatic wavelength at a frequency equal to twice its rotational frequency and with a phase which is a function of the wavelength of the light. As the retardation may be of the order of hundreds or even thousands of orders, it is possible to have a phase difference of π in the rotating Polaroid or 2π in the output for reasonably spaced doublets such as sodium. The output from each of the two lines will then add in phase to give their arithmetic sum in the output. A spectral continuum on the other hand produces no output as each wavelength is approximately matched by another $\pi/4$ difference in phase, so that the vectoral sum of the two terms is a constant. The rejection ratio of a filter of this type may be defined as the ratio of the modulation for the atomic line of interest to the modulation of a blackbody continuum. Modulation is the ratio of the peak AC output to the DC average output. A definition of the resolution of an instrument of this type (radiometer) might be the effective spectral passband of the instrument divided by the rejection ratio.

Adaption of the Above Concept to a Radiometer for Lines and Points

In order to adapt the above birefringent filter concept to a radiometer for lines and points, it must be compatible with a suitable radiometer form. Figure I-4 is a diagram of such an instrument. The objective optics images objects at infinity in the field stop which limits and sharply defines the field of view. A spatial filtering "chopper" placed closely behind the

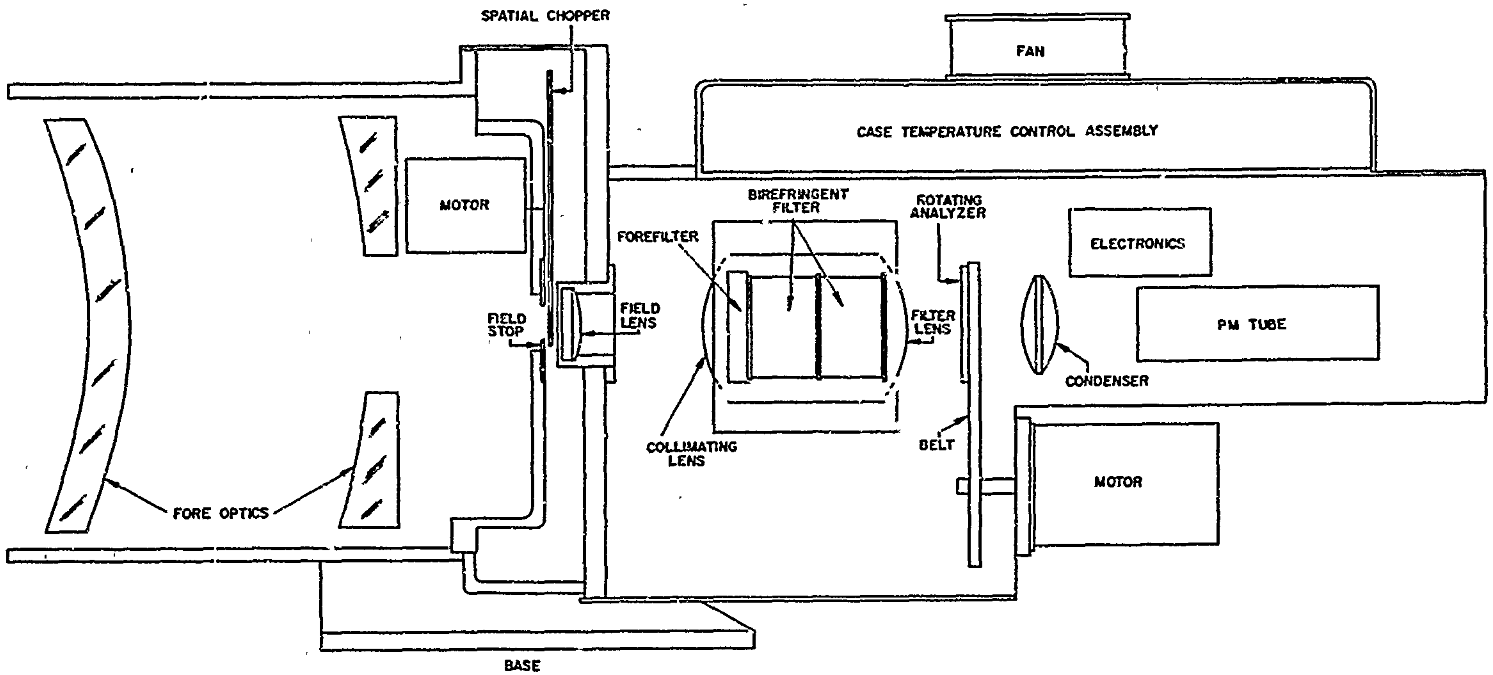


Fig. I-4 A diagram of the atomic line radiometer.

R-8162

stop serves the function of modulating the light from point and line objects at a suitable frequency for the information bandwidth desired and for the electronics and at the same time, not modulating the light from the uniform sky background. The light is then recollimated and passes through the birefringent filter and is collected onto the photomultiplier. The signal from the photomultiplier anode is suitably processed and recorded together with a sync signal for each 180° of the rotating Polaroid.

It is fortunate that the combination of the two concepts gives a functional concept that has many very satisfactory instrumental aspects. Some of these will be discussed in detail in the following portion of the report.

Fore Optics

The fore optics are derived from a Maksutov-Cassegrain.[4] They provide a large aperture, compact system of relatively simple construction. Pertinent data are given in table I-1.

TABLE I-1

RADIOMETER FORE OPTICS	DATA
Aperture, Diameter	17.8 cm
Obscuration	8.9 cm
Area	186 cm^2
Focal Length	43.4 cm
Focal Ratio, Geometric	f/2.4
Effective	f/2.9
Field of View	2.0°
Resolution (measured radially at edge of field of view)	0.11°

Spatial Filter

The spatial filter is a slotted disc placed very close to the field stop to modulate the light from a point target in the field of view. It consists of a disc which has 60 radial slots and blades. It is so designed and placed that exactly 3 periods, 3 slots and 3 blades, will cover the field of view. Under these conditions an approximate theoretical analysis indicates that the modulation of a uniform background would be approximately

1.25%. However, our experience indicates that in practice, probably due to the smoothing effect of the slight but necessary distance between the "chopper" and the stop, it is even more effective and the "rejection ratio" is approximately 100 to 1. The parameter chosen, 60 periods when rotated by a synchronous electric motor at 1800 rpm, gives a modulation frequency of 1800 Hz. This may be considered as a basic carrier frequency for the radiometric information.

Internal Optics

The function of the internal optics is to recollimate the light to the degree required by the forefilter and the birefringent filter and then to condense it to a small, Maxwellian image on the photomultiplier cathode.

Birefringent Filter

The birefringent filter will consist of a selected Polaroid, two selected quartz pieces which will be precisely oriented and made plane parallel and polished, a half-wave plate and a quarter-wave plate of selected and split mica. The free spectral range will be 6 Å at 5900 Å. The aperture is 2.4 inches, so a two-inch collimated beam can be accommodated easily over the angular range required. The second Polaroid will be rotated concentrically with the optical axis to minimize modulation effects due to slight density variations across the Polaroid. The Polaroid will be driven by a precision timing belt at 4500 rpm from a 3600 rpm synchronous motor. The resulting modulation frequency of spectral lines is 150 Hz. The forefilter and the birefringent filter will be suitably insulated and heated by thermostatically controlled elements to maintain a uniform temperature to $\pm$ 0.1°C.

As the temperature of the forefilter must be closely regulated at a chosen temperature and the temperature of the birefringent quartz filter must remain stable (although the exact temperature is not important in this application), the forefilter has been combined with the birefringent filter in an oil immersed unit. The ends of the cell are spherical to act as lenses in collimating the light from the point image in the field of view in the one case and imaging the exit pupil on the photomultiplier photocathode in the second case. This technique, immersion, effectively removes the losses due to Fresnel reflection at fourteen glass-air surfaces which otherwise

would cause a loss of approximately 50% in transmission. Two other lenses are necessary in the internal optics. The field lens assists in imaging the exit pupil of the objective in the center of the birefringent filter so that the collimated beam effectively pivots about the center of the filter as the image of a point object moves to various parts of the field of view. The last lens in the system, the condenser, reimages the exit pupil on the photocathode so that variations in sensitivity will not occur due to movement of the object in the field of view.

Forefilter

The forefilter (for sodium) is specified for .01 transmission at 12 Å from the center frequency and will have one-half of peak transmission at about 6 Å from the center frequency. This is about a 0.2% halfwidth filter, which is rather narrow. It is important, therefore, that the recollimated beam be well collimated and not change angle any more than necessary as the target moves to different portions of the field of view. Data available from the forefilter manufacturer indicates that, at an angle of 3-1/2° from the normal, the peak transmission wavelength of such a filter would shift approximately 2.8Å. This is about one-half of the distance from the peak to the half-power point on the filter, so this portion of the design must be very carefully carried out and the results, since the theory is inexact, must be evaluated carefully.

The angular deviation of the beam from the normal will be equal to the angular magnification of the system at that point as the half field is one degree. For a 2-inch beam, the value is 3 1/2°. In considering the effect of this on the forefilter passband and the birefringent filter, the angular aberrations must be added to the above figure.

Photomultiplier

The photomultiplier will be an EMR 541E-01 with selected S-20 cathode for maximum signal to noise at 5900 Å. It will be shielded both magnetically and electrostatically to minimize disturbing effects due to motors and power supplies within the radiometer case.

Electronics

The electronics will provide for two channels of signal recording and a sync signal of 0.5 to 1 volt for each 180° of rotation. The signal channel amplifiers will be provided with limiting on the upper end in such a manner that the output will not become double valued. A special circuit, as shown in figure I- 5 will provide a dc test point at the anode of the photomultiplier to be used in maintenance and testing.

A minimum of filtering is provided in the signal processing electronics before the signal is recorded in order that troubleshooting can be done at the data reduction stage if necessary.

The threshold will be at a level of 625 photoelectrons/second from a selected EMR 541E photomultiplier with an S-20 photocathode. This is equivalent to a current of 10^{-16} amperes. With the photomultiplier gain of 10^6, this will provide 10^{-10} amperes to the input of the preamplifier. The signal levels at various points in the circuit for the entire five decades of dynamic range are shown in Table I- 2.

A frequency space diagram of the signal is shown in figure I-6. The tape recorded signal will be reduced by suitable filtering to determine the total irradiance due to the target in the passband of the forefilter and the irradiance due to the atomic line alone. The spatial continuum due to the sky background is expected to amount to some 1000 photons per second and, as the photocathode efficiency is nowhere appreciably above .20, this source will contribute a noise of less than 35% which will not significantly change the threshold.

TABLE I-2

SIGNAL LEVELS IN RADIOMETER ELECTRONICS

PMT Cathode Electrons per Second	PMT Anode Current in Amps	Preamp Output in Volts		Scaling Amp Output in Volts	
		Direct	Chan. 1	Direct	Chan. 2
6.25×10^2	10^{-10}	10^{-4}	10^{-5}	5×10^{-2}	5×10^{-3}
6.25×10^3	10^{-9}	10^{-3}	10^{-4}	5×10^{-1}	5×10^{-2}
6.25×10^4	10^{-8}	10^{-2}	10^{-3}	5	5×10^{-1}
6.25×10^5	10^{-7}	10^{-1}	10^{-2}	non-linear	
6.25×10^6	10^{-6}	1	10^{-1}	non-linear	
6.25×10^7	10^{-5}	10	1	non-linear	

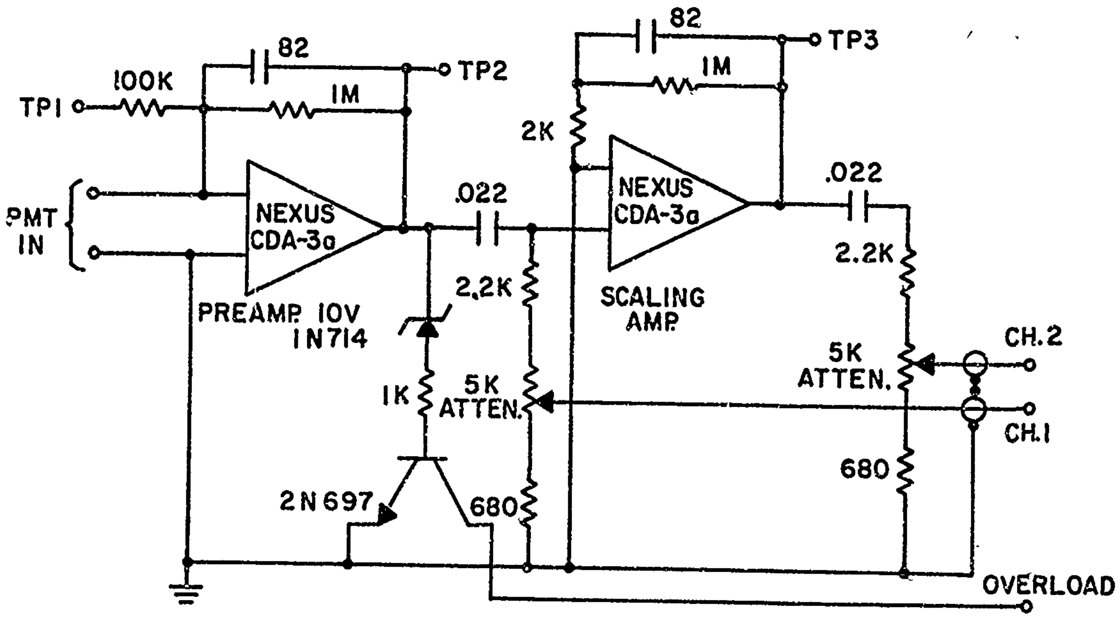


Fig. I-5 Signal processing electronic circuitry.

R-9070

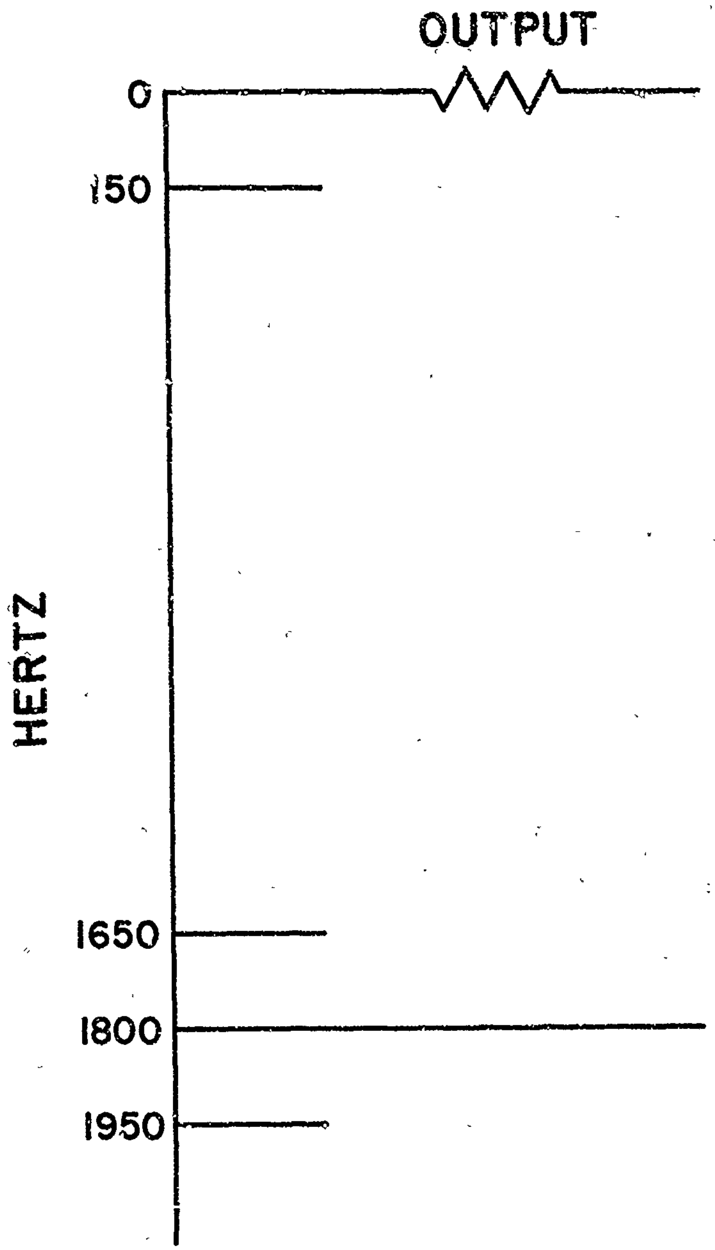


Fig. I-6 Frequency space diagram of signal output from photomultiplier. The dc signal is available only at test point (TP2) for purposes of adjustment and maintenance. A second test point (TP1) is available for the injection of test voltages in calibration.

R-9268

As indicated in Table 1-2 the scaling amplifier output will be 5 millivolts at the threshold. Due to the shot noise of the 625 cathode electrons per second at threshold, it will be necessary to use a filter bandpass of approximately 8 Hz to have an effective 10:1 signal-to-noise ratio. As the tape recorder noise specification is that noise is down 43 db below one volt at 20 kHz, tape noise will be approximately 140 microvolts in this bandpass and thus negligible.

Sensitivity

The threshold of the instrument will be 625 photoelectrons per second. At a quantum efficiency of 0.07 (S-20 at 0.59μ), this corresponds to 9000 photons per second or 3×10^{-15} watts. As the aperture area is 186 cm^2 and the transmission ~ 0.05 for the entire instrument, the threshold level of irradiance is approximately 3.23×10^{-14} watts/cm^2 for sodium. For a black body continuum, the corresponding threshold is 2.7×10^{-11} watts/cm^2-micron which is roughly equivalent to 2700 watts per steradian at 100 km, or a star of -2.5 stellar magnitudes. Therefore, no problem is expected with stellar background.

4.3.2 A Fabry-Perot Etalon Spectrometer (R. Prescott)

Introduction

Since the report on the etalon status included in the last Semi-annual, the instrument has been mocked up in the laboratory and further testing accomplished. However, a considerable amount of further laboratory work is still necessary before a field instrument can be designed. Various techniques must be developed and evaluated. The prime objective of this work will be to achieve a design sufficiently stable in a field environment to allow the achievement of resolution which has already been obtained in the laboratory. It is likely that in view of these difficulties, the first field instrument may be designed primarily to evaluate these design factors.

The material presented below has been submitted in TRAP Memorandum No. 7, in partial fulfillment of Task 4.3.2.

Concept of the Instrument

The etalon consists of two extremely flat surfaces which are mounted closer together, perfectly parallel, and separated by a distance t. A beam of light falling on the etalon with an angle to the normal of 0 is partially

reflected and partially transmitted. At each surface the transmitted waves are coherent, and their amplitudes add. The resulting transmission is a function of 0 and is given in the first equation

$$\tau = \frac{T^2}{(1 - R)^2} \frac{1}{1 + (\frac{\pi}{2})^2 f^2 \sin^2 \pi n} \qquad (1)$$

where τ is the transmission of the etalon; T is the transmission of each plate; R is the reflectivity of each plate; f is the finesse; and n is the order number. The finesse of a Fabry-Perot etalon is a measure of its resolving power and is determined in part by the reflectivity of each element according to the second equation

$$f = \frac{\pi R^{1/2}}{1 - R} \qquad (2)$$

A plot of the transmission for various values of finesse is shown in Figure I-7. It will be noticed that the finesse is the ratio of the angle between orders to the angle between the half-power points of an infinitely narrow line and thus is a measure of the number of resolved elements that can be accommodated in a single, free spectral range. The actual finesse that can be achieved is determined not only by the reflectivity of each surface but also by its flatness and smoothness, and in a photographic instrument is also determined by the resolution of the lens and film system used to record the data. The third equation

$$\tau_{max} = \frac{T^2}{(1 - R)^2} = \frac{1}{(1 + A/T)^2} \qquad (3)$$

where A is the fraction of the incident energy absorbed, shows the value of the maximum transmission and indicates that if the efficiency of the

reflecting surface is high (where efficiency is defined as the sum of the transmitted and reflected wave) then the maximum transmission of the etalon can approach unity. Three equations

$$\Delta\lambda = \lambda/n = \text{free spectral range.} \tag{4}$$

$$\frac{\lambda}{\Delta\lambda} = fn = \text{resolving power} \tag{5}$$

$$f = \frac{\Delta\lambda}{\delta\lambda} = \text{finesse} \tag{6}$$

indicate the relationship between the free spectral range and the resolving power, and again define finesse. Equation (7) defines the angle to a particular fringe in terms of the order number for the central fringe of this same wavelength.

$$\theta_K \sim \sqrt{2K/n_o} \tag{7}$$

Looking again at figure I-7, we can see that resolving power may be held constant, in this case at 1/8 angstrom, and the free spectral range increased if the finesse can be correspondingly increased. If the entire field to the left of the etalon is filled with monochromatic light and a lens is placed behind the etalon, the pattern on the focal plane is a measure of the transmission function of the lens for the monochromatic light as indicated in equation (1). This pattern is shown schematically in figure I-8. It will be noticed that if the axis of the etalon is tilted suitably with respect to the axis of the camera a region can be found in which the field format will be filled with a pattern of nearly straight, nearly equally spaced parallel lines as indicated. If, now, an astigmatic lens, a cylinder of suitable power, is placed to the left of the etalon, as shown in figure I-9a a line object in space will be blurred and its image widened until it covers just slightly more than one free spectral range, while at the same time spatial resolution will be maintained in the direction along the length of the line. A filter is now

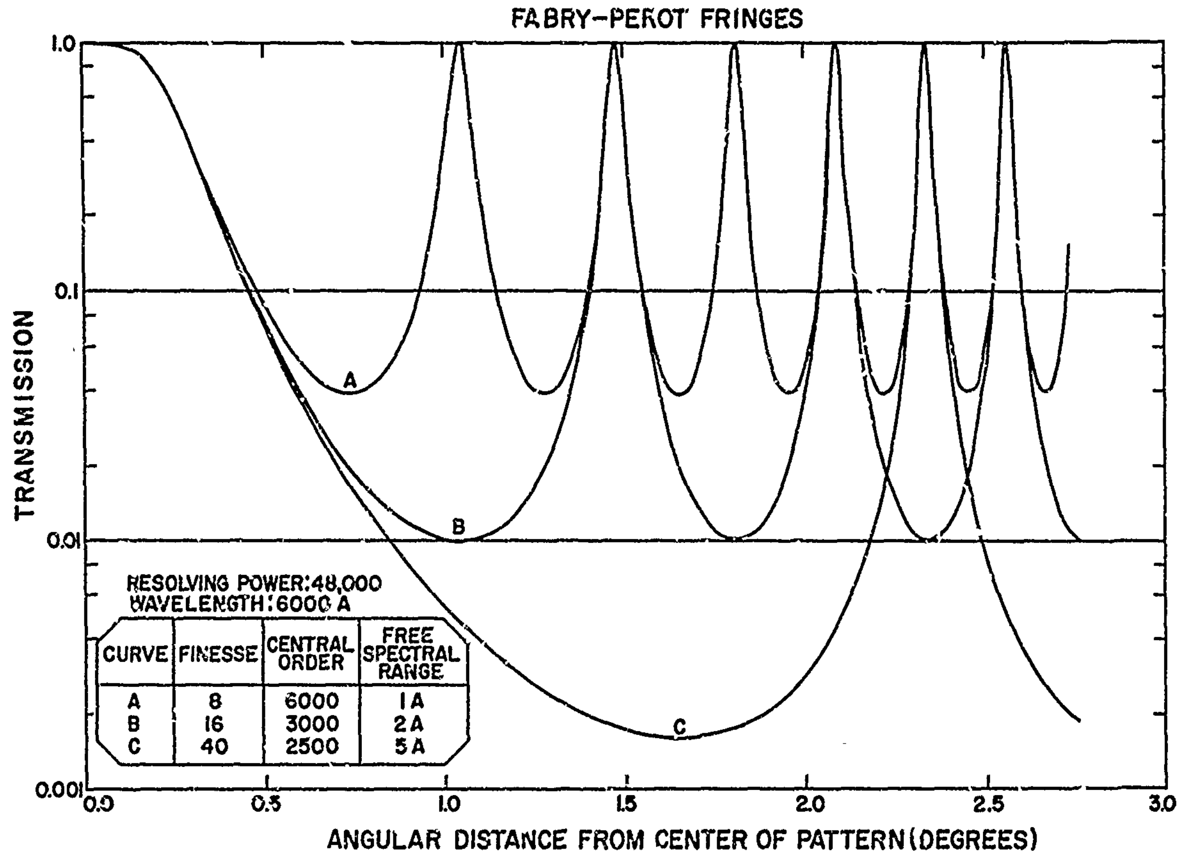


Fig. I-7 Transmission of a Fabry-Perot etalon for various values of finesse.

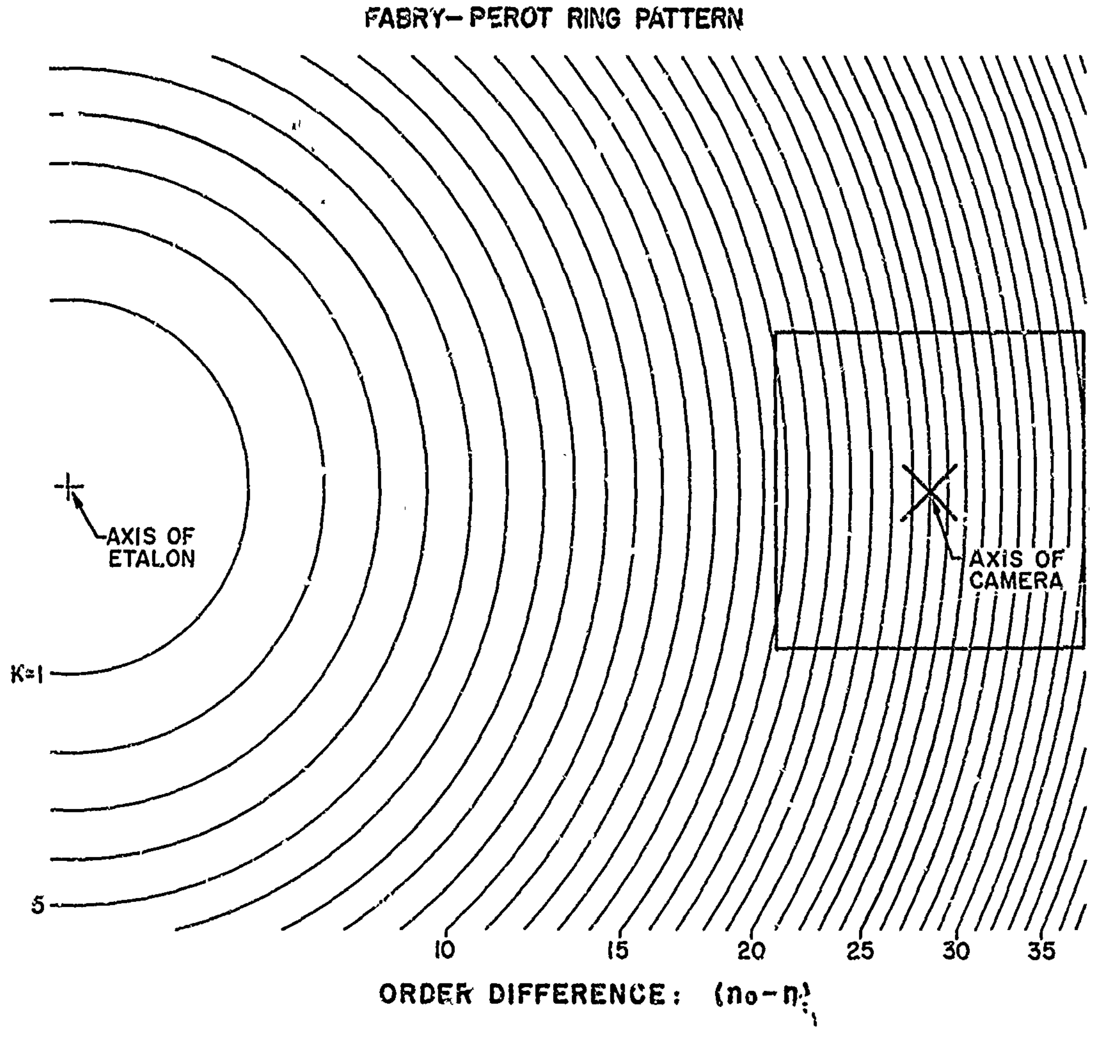


Fig. I-8 A sketch of the Fabry-Perot pattern for a single monochromatic line. A suitably chosen camera field may consist of nearly parallel, nearly uniformly spaced lines.

HIGH SPECTRAL RESOLUTION ETALON INSTRUMENT

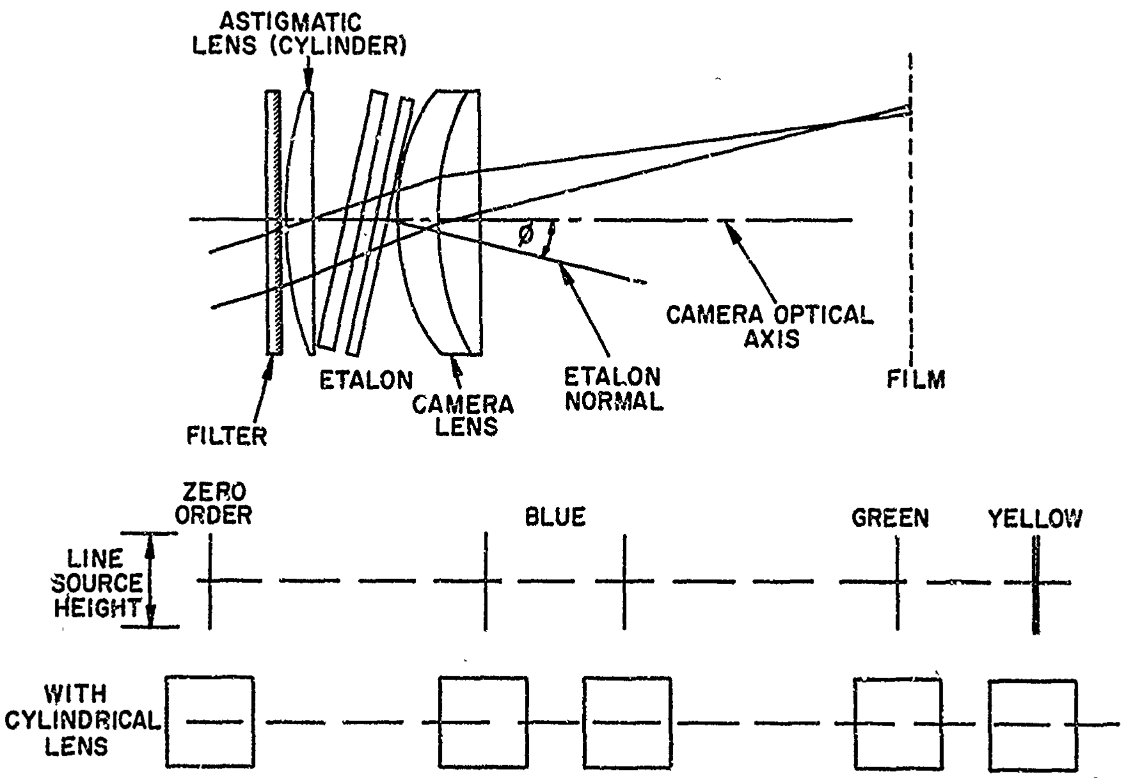


Fig. I-9a A diagram of a camera-etalon system for producing high spectral resolution images with spatial resolution in one direction.

R-9270

placed in this system to exclude light outside of the free spectral range. Figure I- 9b shows an image made with such an arrangement in the laboratory using a sodium source without the etalon. A similar image would be seen if the source were white light. Figure I-9c shows the results when the etalon is used. In this case, the free spectral range is approximately 0.62 Å and both sodium lines are shown.

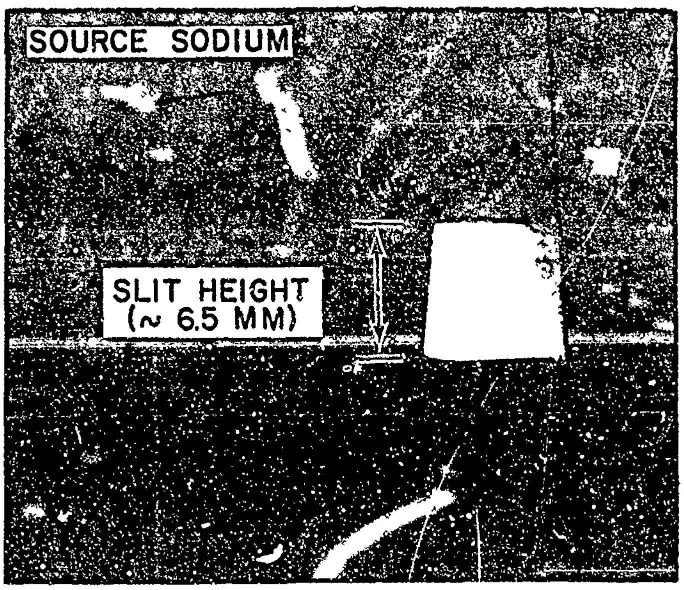
When one speaks of free spectral ranges of a few angstroms, and here we are speaking of free spectral ranges as small as a fraction of an angstrom, the difficulty of finding a suitable filter is great and it is impossible to procure such a filter which has a tolerance of more than a fraction of a degree in collimation or more than an inch or two in diameter. This difficulty causes us to look for another method of isolating lines and preventing overlap of orders for different lines. This has been done by using a grating to replace the filter. A schematic of this instrument is shown in Figure I-10a. In figure I-10b the zero order, the blue, the green, and the yellow lines of mercury are shown schematically for a line source a as separated by a system consisting of the grating and the camera lens only. Figure I- 10c shows the broadened images which would occur when the cylinder lens is inserted. Such a system was tested, and figure I-11 shows a portion of the resulting spectrum. In this case the astigmatism caused by the cylinder is excessive and, as a result, approximately four orders are shown for the mercury green line and not quite that much for the mercury yellow doublet. As an indication of the type of resolution that can be expected from such a system, a microdensitometer trace was made of the mercury green line shown in figure I-11. This is shown in figure I-12. It is quite evident that the resolution is at least as good as 1/20 of an angstrom, which correspond to a resolution of more than 100,000.

Instrument Development

It is clear that an instrument capable of producing extremely valuable high spectral resolution re-entry data is theoretically feasible, and the concept has been mocked up and demonstrated in the laboratory. However, before such an instrument can be successfully used in the field, a number of very difficult problems must be solved, as follows:

LINE SOURCE PHOTOGRAPH WITH CYLINDRICAL OPTICS

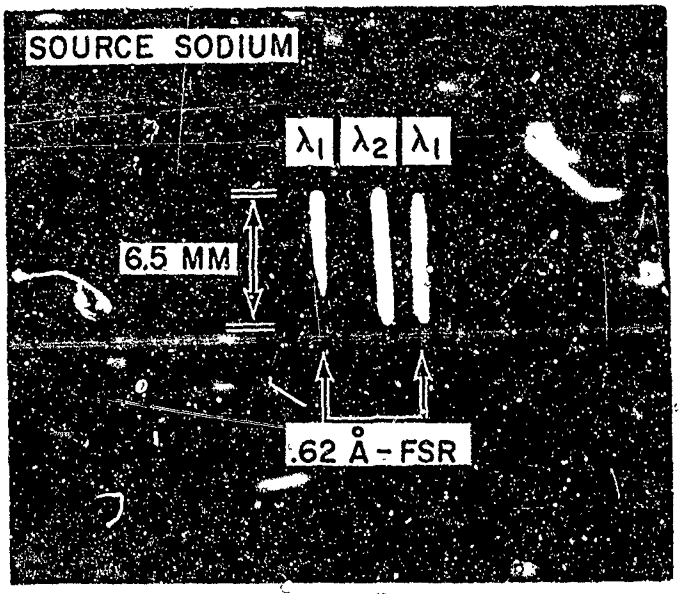
DIRECTION OF SPREADING
BY CYLINDRICAL OPTICS



SLIT WIDTH IS .01 MM"

Fig. I-9b Image of an unresolved line as blurred by an astigmatic camera objective.

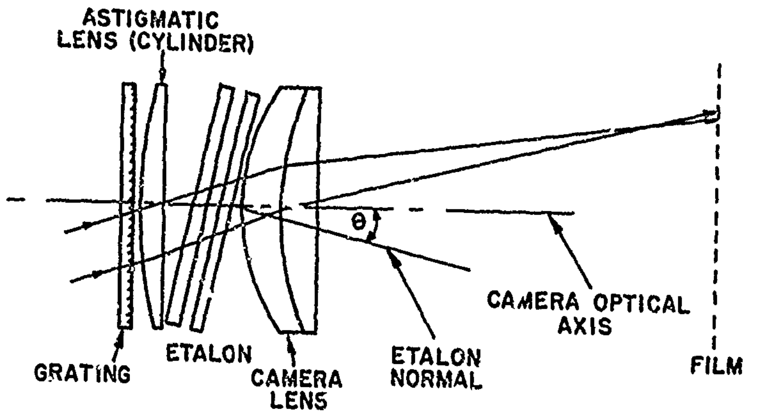
LINE SOURCE PHOTOGRAPH WITH CYLINDRICAL OPTICS AND FABRY-PEROT ETALON



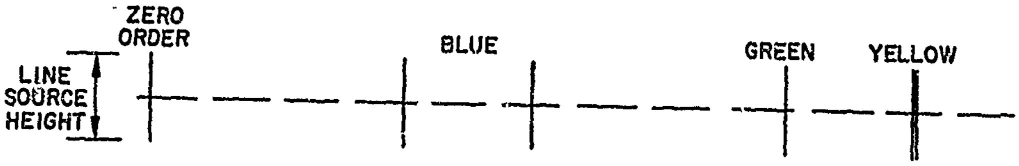
SLIT WIDTH IS .01MM"

Fig. I-9c Image of a sodium source with an astigmatic camera objective and a Fabry-Perot etalon.

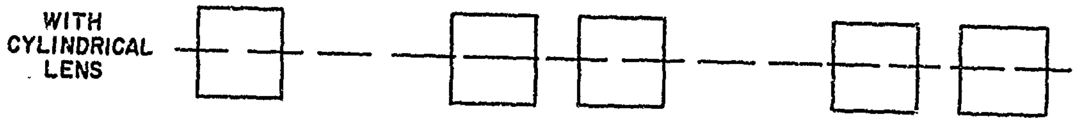
HIGH RESOLUTION ASTIGMATIC OPTICAL SYSTEM



(A) ARRANGEMENT OF COMPONENTS



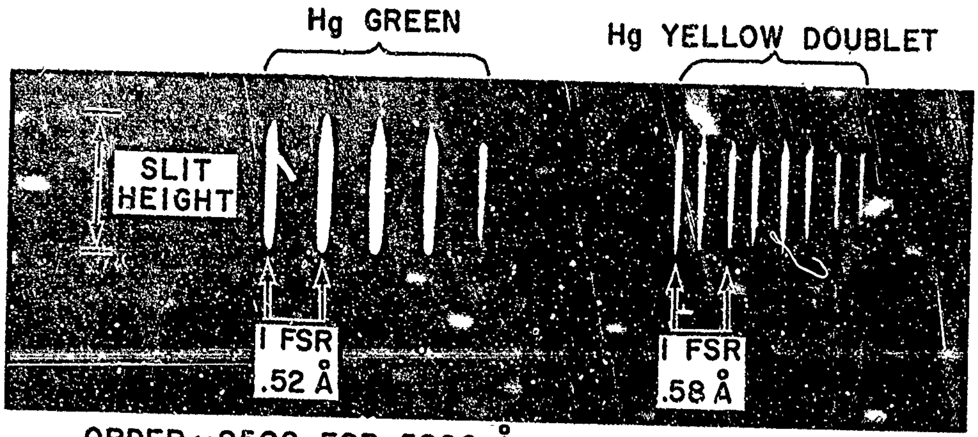
(B) SCHEMATIC OF LINES AS SEPARATED



(C) SCHEMATIC OF LINES AS SEPARATED AND BROADENED

Fig. I-10 Isolation of line spectra for the etalon instrument by the use of a grating.

LINE SOURCE PHOTOGRAPH WITH CYLINDRICAL OPTICS, ETALON, AND 300 ℓ/MM GRATING



ORDER ~ 9500 FOR 5890 Å   t = 120 SEC.

Fig. I-11   A photograph of a portion of a spectrum using the system diagrammed in Fig. I-10.

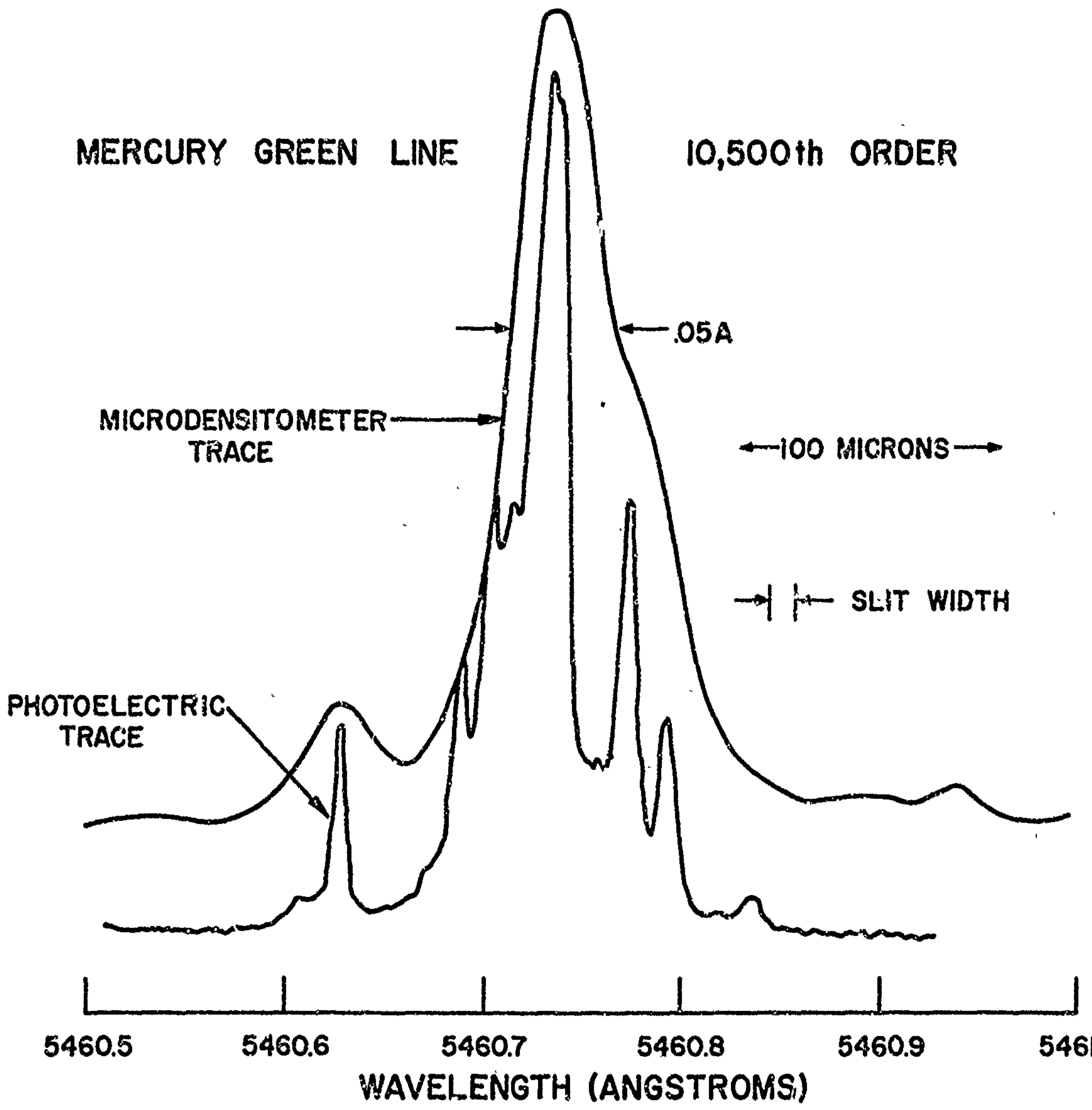


Fig. I-12 A microdensitometer trace of a portion of the data shown in Fig. I-11. A photoelectric trace from a high dispersion laboratory instrument is shown for comparison. (Adopted from American Institute of Physics Handbook, McGraw-Hill, 1957, pp 7-119).

1) The plates themselves must be extremely flat, well polished and rigid enough to hold this flatness in the aircraft environment.
2) The plates must be coated with a material of high efficiency and high reflectivity, and these parameters must be essentially constant over the useful spectral range of the instrument.
3) The plates must be mounted so that they can be adjusted to perfect parallelism and held in this manner without being twisted to the slightest degree in the aircraft environment.
4) The etalon must be suitably protected, both from the mechanical vibration and severe temperature variations of its aircraft environment.
5) The etalon must be combined with a recording camera of suitable characteristics.

It is proposed to make a careful evaluation of each of these problem areas in the course of developing the preliminary system design.

Performance Specifications

Although at this stage a great deal remians to be learned about the capabilities of a high spectral resolution instrument based on the concept described herein, it is nevertheless thought worthwhile to make such an estimate in order to facilitate discussion of its possible usefulness in the TRAP program.

The most important parameters of the final instrument will be aperture and finesse. Let us assume that we can achieve a satisfactorily stable instrument with an aperture of 4 inches. One can estimate an efficiency of 0.8 for the grating and a transmission of 0.5 for the etalon, and 0.7 for the lens. If a finesse of 20 is achieved, it will be necessary to spread the image somewhat more than this number times the resolution in order to insure a spread of at least one free spectral range. Let us assume a focal length of one meter. A wake length of 100 meters would then appear as an image on an area of one square millimeter. A very sensitive film will require an exposure of about 5×10^{-4} ergs/mm^2 for a detectable image. So we have, for 1/100-second exposure

$$\frac{\text{Watts/meter-}\Omega \times 100}{10^{14}} \times \frac{\pi}{4} 100 \times 0.8 \times 0.5 \times 0.7 = \frac{5 \times 10^{-4}}{10^7 \times 10^{-2}}$$

$$\text{Watts/meter} = \frac{5 \times 10^{-4} \times 10^{14}}{0.28 \times 10^4 \times \frac{\pi}{4}}$$

$$= 220 \text{ watts/meter - } \Omega \text{ in a resolution element.}$$

It is evident that an increase of sensitivity beyond this would be desirable. The use of an image intensifier would drop the above threshold by at least two orders of magnitude.

Tentative Specifications for a High Resolution Spectral Instrument

Aperture, millimeters	100
Focal Length, millimeters	1000
Exposure Time, seconds	1.01
Spatial Resolution, meters at 10^5 meters	4
Spectral Resolution, Angstroms	0.05
Sensitivity, watts/meter*	200
Spectral Region, Angstroms	4000 - 8000

It is clear that the rejection of continuum background in such an instrument would be excellent due to the effect of the grating and due to the added effect of the etalon which would be equal to its finesse.

Conclusions

An instrumental concpet has been experimentally proven in the laboratory which gives promise of providing all of the spectral resolution which may be required for the determination of spectral line detail in re-entry monitoring. A great deal of development is required before the design of a field instrument can be carried out, and field testing of the first design will be necessary before the ultimate resolving power which can be attained is determined. The data from an instrument of this type can give a great deal of insight into re-entry physics through the determination of line broadening, self-absorption, etc., in the various flight regimes.

* In a single atomic line

Image Intensifier Cine Spectrograph System (R. Prescott)

Introduction

An image intensifier cinespectrograph system design has been completed. This design is summarized in this section.

The aim of the design is to improve the instrument in respects such as size, weight, and reliability while at the same time improving its data taking capabilities with respect to spectral and spatial resolution, dynamic range, persistence, and ultraviolet transmission.

An image intensifier cinespectrograph has limitations of sensitivity, resolution, dynamic range, spectral range, persistence, and many others. In our experience to date on a 3-stage instrument, we have found that the following characteristics limit the data:

a) Persistence, or a long-term afterglow from a strong image
b) "White out," or a general background increase due to objects both within and outside of the field of view
c) Poor resolution
d) Poor UV response
e) Vignetting
f) Limited dynamic range

It is expected that each of these factors will be significantly improved in the advanced design. The objective system will be much better corrected for aberration, its UV transmission will be good to below atmospheric cutoff, and vignetting will be negligible. An attempt will be made to get a great improvement in the micro smoothness of the objective optics. These precautions will cause an improvement in "white out," resolution, UV response, and vignetting characteristics of the instrument.

Dynamic Range of the Spectrograph

The dynamic range of a spectrograph may be defined in various ways. One basis for definition would be the range in which the spatial and/or spectral resolution were within a factor of, say, two of the peak. A second basis would be the range in which useful information could be extracted from the data. It is obvious that the values given in the two cases would be vastly different for any given spectrograph, regardless of its design. On the basis of the first definition, one may expect perhaps an order of magnitude at

best from any instrument recording images on film. The second basis will give, using special films and/or development techniques, ranges of perhaps $10^6 - 10^7$.

Based on the above definitions, it is expected on the basis of our experience that a 2-stage instrument will have a dynamic range of the first type which is about an order of magnitude and limited by the film. The dynamic range of the second type will probably be limited by the intensifier tube and when using a 2-stage tube, is expected to be vastly improved over a 3-stage tube.

The apparent limitation of dynamic range of the second type is due to a background buildup which is proportional to the total signal. An explanation for this has been found, and a means for alleviating it is now being explored with the manufacturer of the tubes.

The image tube will be a modified version of RCA's C33034A. The manufacturer of the tube is being asked to modify its design to improve performance with bright objects in the field of view. Specifically, he is being asked to use a dark aluminum on the phosphors to prevent a feedback effect which causes "contrast dilution" by reflecting light back over the entire photocathode that is transmitted through the photocathode initially.[5] A quotation is also being sought on a sapphire faceplate to improve the uniformity of the resolution which is affected by local defects in the faceplate.

An S-20 surface was chosen because it is superior to any other photoemissive surface in sensitivity and spectral range. Its UV cutoff is dictated by the photocathode window, and we specify the substitution of a UV transmitting glass in this window for the borosilicate glass normally used. The resulting photocathode suffers no significant drop in sensitivity until the wavelength is well below 3000A. This is appreciably below the effective atmospheric ozone cutoff of 3200A. On the other hand, the effective sensitivity of this surface extends to approximately 8000 A in the infrared where its quantum efficiency is equal to that of an S-1 surface and its dark current (at room temperature) a factor of 10^4 lower.

The selection of this surface, therefore, allows us to have a choice of two spectral ranges in the instrument: UV, 3000 - 6000 A, and visible infrared, 4000 - 8000A. The change from one range to the other is accomplished by substitution of a different grating and filter, easily done in the field.

Figure I-13 shows the required tube gain for several films as a function of the transfer optics effective focal ratio. Two-stage image intensifier tubes investigated by AERL have gains ranging from 5250 to 9500. With these gains and the fastest available films, an effective focal ratio of f/3 to f/4 is required to attain optimum sensitivity. As a practical matter, a moderate loss of sensitivity could well be tolerated, particularly if accompanied by the improved resolution, dynamic gain, and persistence characteristics.

It should be noted that the 2-stage tube is rated at 40-45 line pairs per millimeter, compared to the 20-25 line pairs per millimeter rating for the 3-stage tube used in the first image intensifier fabricated by AERL. It will be necessary to substantially improve the objective optics and the transfer optics over those in the present instrument to take advantage of the improved resolution of the 2-stage tube.

Of four 2-stage tubes on which we have seen the specifications, the resolution has been given as 40 or 45 line pairs per millimeter in the center of the tube and 32 line pairs per millimeter at the edge of the tube. It has been learned through careful inquiry that this resolution refers to the frequency at which the modulation transfer function (MTF) of the tube is .02. Tentative data on the form of the MTF curve for these devices indicates that the MTF will be approximately 40 to 50% at one-third of this frequency. Experience indicates that this excellent objective and transfer optics will enable us to realize a resolution on film corresponding to the 40 to 50% MTF level of the tube. As all of the optics tend to have a somewhat better resolution at the center than the edge, it is expected that the resolution at the edge of the field will be perhaps 10 lines per millimeter referred to the tube compared with an expected 15 lines per millimeter at the center of the tube.

Sensitivity of the Spectrograph

In view of the fact that most of the useful dynamic range of the present instrument is below the intensity level at which acquisition normally occurs, no particular attempt is being made to maintain the extremely high sensitivity of the present instrument. Instead, it is being designed with the objective of achieving high resolution, minimum vignetting, and wide dynamic range. It is likely that as a result of the trade-offs made, the threshold will

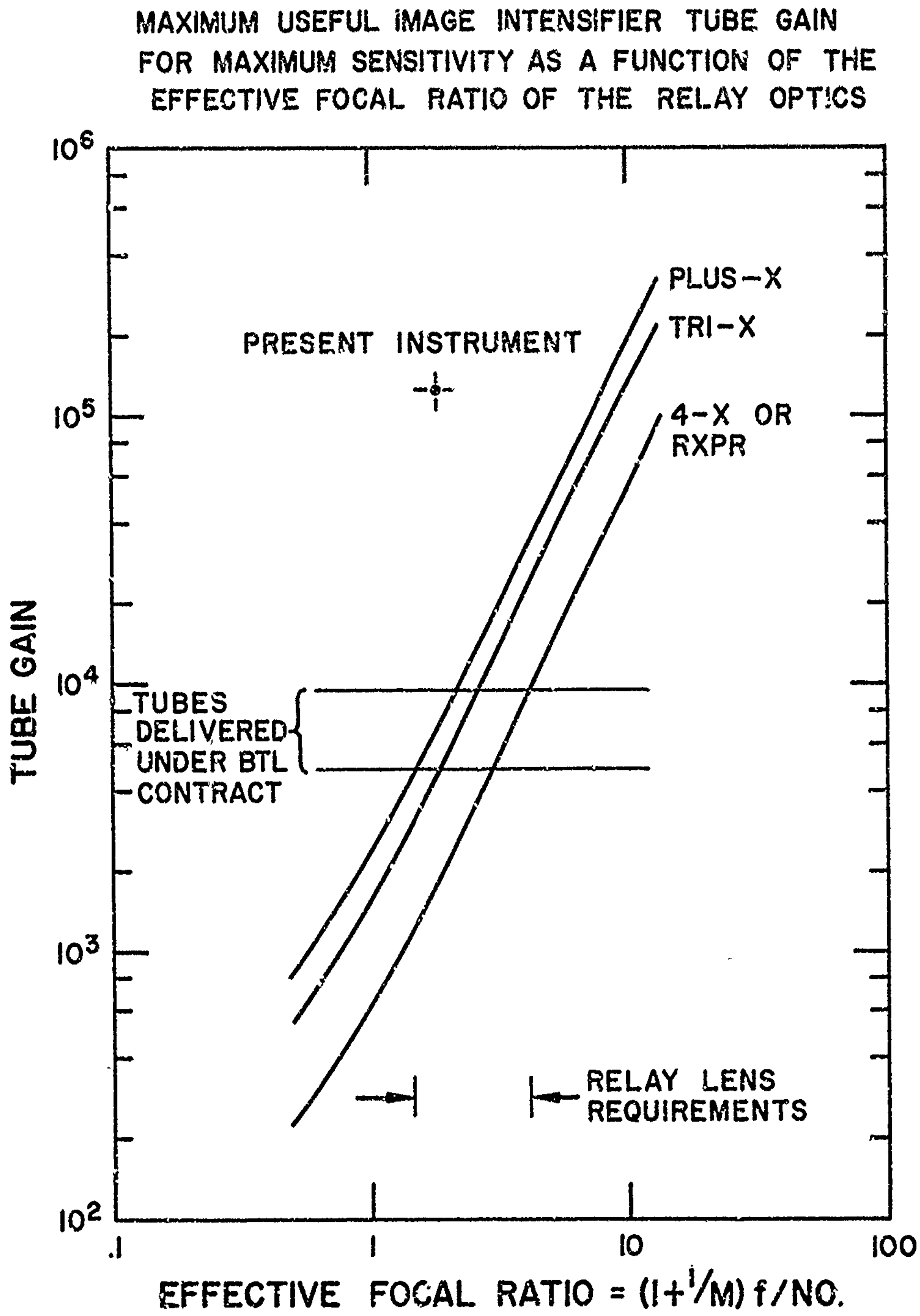


Fig. I-13 A plot showing the required gain and effective aperature ratio required for several film types to achieve maximum sensitivity. The range of gains for four 2-stage tubes is shown, together with the required range of effective focal ratio in the transfer optics.

increase by perhaps a half order of magnitude. If we apply this factor to the thresholds determined for the first instrument, we have the values given in Table I-3.

TABLE I-3

IMAGE INTENSIFIER SENSITIVITY

Point Source (Basis, Stellar Calibration)	
Threshold - at 100 km	10^{-2} watts/ster
Dispersed Point Source (Line Spectrum) (In-Lab Calibration)	
Threshold - at 100 km	6 watts/μ ster
Spectral "Area" Source (Wake Continuum) (from In-Lab Calibration)	
Threshold - at 100 km	6×10^{-2} watts/M-μ-ster
Night Sky Radiation*	6×10^{-11} watts/cm^2-ster
Resolution Element (Both In-Lab & Stellar)	
at 100 km	9 Meters

*Adapted from Chapman & Carpenter, 1961.

Performance Specifications

The expected performance specifications of the final instrument are given in Table 1-4 and an outline diagram of the system is shown in figure I-14. The field of view is the total tolerance in pointing before any of the spectrum from a point object is out of the field. The transmission and correction of the fore optics will be good to 0.3 micron which is below the atmospheric cutoff due to ozone. The fore optics will be a specially designed Schmidt-Cassegrain with excellent correction and transmission over the entire field of view (2.9 degrees) for all wavelengths from 3000-8000A. The photocathode window of the tube will transmit with negligible absorption to below 0.3 micron also. The 150 line/mm grating will be fabricated with an ultraviolet transmitting material on a fused quartz blank. No filter will be used with this grating, so that above 6000 A a second-order spectrum from the shorter wavelengths may overlay the first-order spectrum. This is due to the fact that no suitable long wavelength cutoff filters of high transmission in the passband are obtainable. The spectral and spatial resolution is based on an expected resolution of 15 line pairs per millimeter referred to the tube image, or 30 line pairs per millimeter referred to the film. This target specification is based on a 50% modulation transfer function value estimated for this spatial frequency for the image tube based on an extrapolation of extremely scanty data from the manufacturer. A further input to this estimate is the availability of a new film from Kodak with a speed comparable to Type 2475 (the fastest previously available film), but with an MTF of 70% at 30 line pairs per millimeter instead of 35%.

The focusing magnet as currently planned will be a prefabricated one piece Alnico V construction with soft iron pole pieces to shape the field. A field uniformity of better than one percent is expected. An alternate design using ferrite is being investigated, but adequate information for its evaluation is not yet available.

The transfer lens is still unspecified. A careful search is still being made for a suitable lens, but so far none of thoroughly satisfactory characteristics have been found. The lens desired would need to have an

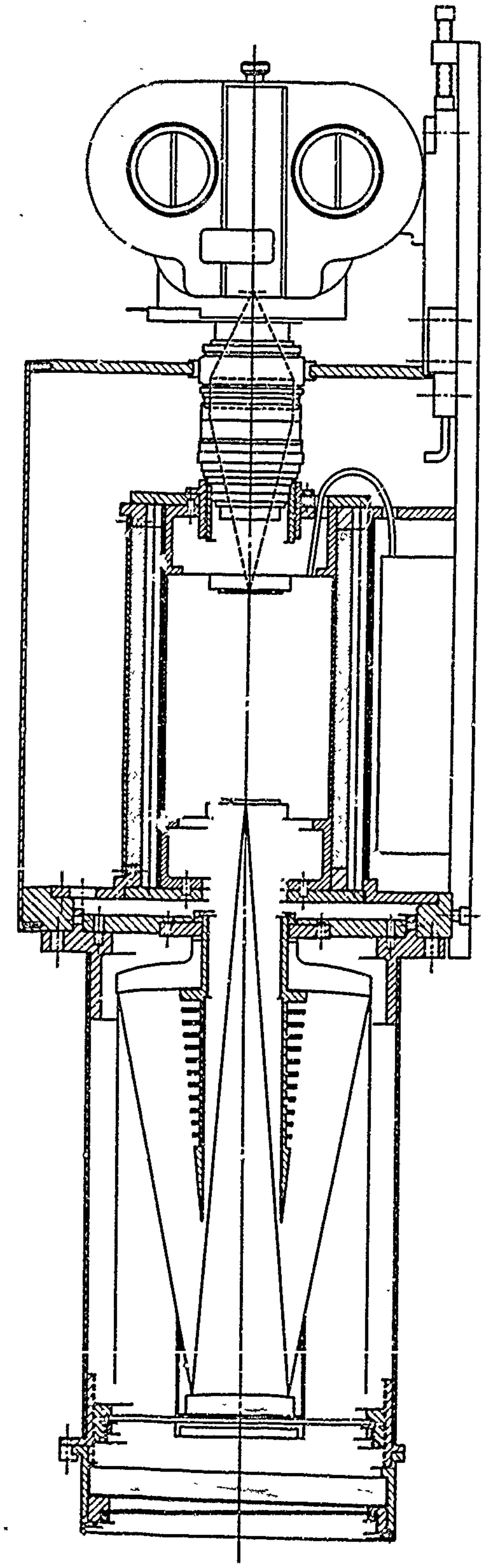


Fig. I-14 A schematic of an image intensifier spectrograph.

R-6202

TABLE I-4

IMAGE INTENSIFIER PARAMETERS

Image Tube, 2 stage, magnetically focused.	
Gain	5000 - 10,000
Resolution (2% MTF)	~ 40-45
Photocathode Diameter, millimeters	38.1
Magnification, Photocathode-to-Phosphor	1
Photocathode	S-20
Output Phosphor	P-11
Photocathode Window, Ultraviolet Transmitting	
Objective, Cassegrain Type	
Aperture, millimeters	150
Focal Length, millimeters	750
Wavelength Range, Transmission and Correction, microns	0.3-0.8
Transfer Optics	
Magnification	0.5
Effective Aperture Ratio	3 - 4
Camera	
35 mm, single frame, 100-foot capacity 40 frames/second for 40 seconds	
Field of View	
Vertical	1.2°
Horizontal	2.9°
Gratings	
75 lines/millimeters	
150 lines/millimeters	

effective f/number in light gathering power of 3 to 4 which, at the magnification of 2:1, would mean an infinity f/number of 1 to 1.3. It should be adequately corrected to permit a resolution of 30 to 40 lines/mm over the entire format in P-11 light and should have a minimum of vignetting loss at the edge of the field.

The camera will almost certainly be a Traid 75 due to its small size, light weight, and reliability.

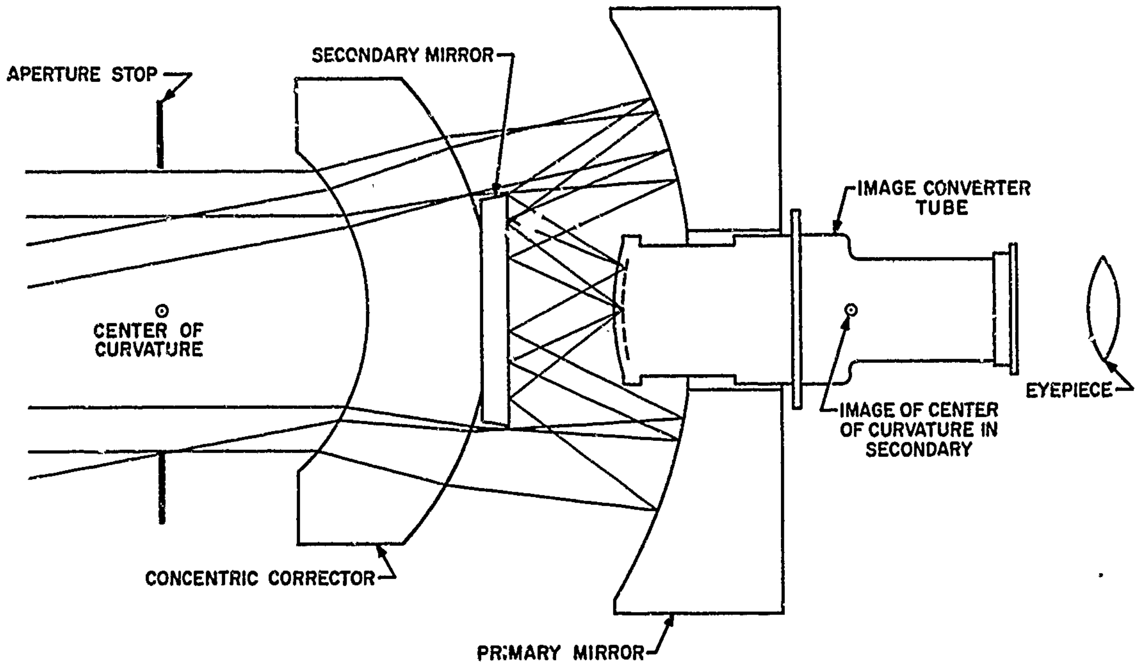
As a result of all of the changes which have been made, to the design of the original instrument, and these include all components of the system with the exception of the gratings and the camera, it is expected that the dynamic range will be greatly increased, the resolution will be greatly increased, the vignetting will be significantly reduced, the UV response will be brought down to below the atmospheric cutoff, and the persistence will be significantly improved. It is expected that the resulting instrument will be very nearly optimum for the TRAP system requirements.

Image Converter Sight

The sensitivity of the image intensifier cinespectrograph is such that it will produce excellent spectral data on bodies whose radiant intensity is well below the visual acquisition level with the naked eye,[6, 7] as well as those whose radiation is largely in the violet and ultraviolet where the sensitivity of the eye is greatly reduced.

A study[8] has indicated that nearly an order of magnitude in acquisition threshold may be obtained by means of passive optical instruments while retaining a large enough field of view for acquisition under normal field conditions. However, due to the ultraviolet sensitivity of the proposed instrument and the relatively large amounts of UV already shown by the first image intensifier instrument with its limited ultraviolet response, it is believed that an image converter sight is a more logical choice. A study[9] has been made, and the results indicated that a suitable instrument could be designed.

Accordingly, the preliminary design specifications of a suitable image converter sight are shown in table I- 5. The optical layout of the sight is shown in figure I-15. So far, a wide-angle eyepiece of 11 mm focal length



BOUWERS CONCENTRIC SYSTEM

Fig. I-15 A schematic of a simple, functional design of image intensifier acquisition and tracking sight. It has a 20° field of view and a magnification of three times.

has not been found. The substitution of the available 16 mm eyepiece will reduce the apparent field of view to 43 degrees and the power to two. This will result in a loss of about two in sensitivity from that quoted in Ref. 7 so that it will still be somewhat below the threshold of the instrument which is estimated to be 6×10^{-16} watts/cm^2 -micron.

TABLE I- 5

SPECIFICATIONS OF IMAGE CONVERTER SIGHT

Objective Optics, Bouwers Concentric	
Focal Ratio	f/1
Field of View	20°
Focal Length	61 mm
Image Intensifier	
Photocathode	S-20
Phosphor	
Luminous Gain	150-300
Magnification	0.5
Resolution (referred to photocathode)	35 lines/mm
Eyepiece	
Focal Length	11 mm
Field of View	60°

4.5.1 TRAP-6 Pointing System Evaluation (J. E. Nunes)

The installation of the gimbal system on the TRAP-6 aircraft was completed in October 1966 and the efforts relevant thereto were outlined in the last Semi-Annual Progress Report. Since that time, several missions have been monitored and these, as well as others to be covered over the next few months, are being utilized as one of the bases for the performance analysis of the pointing system. Under evaluation are the effects on system performance caused by the angular error sensor, gimbal design logic, the translating platform in the open cargo door, etc., as well as the human engineering aspects of joystick acquisition. Work has been proceeding in all of the aforementioned areas and the report on this study, scheduled to be published in October, will be prepared in accordance with the following outline:

I. System Description: The initial section will contain a description of the pointing system so as to allow the report to be read without extensive reference to other documents.

II. System Operation: This section will contain a presentation of the significant events relevant to the evaluation and will include a summary of missions covered and equipment performance throughout the period of evaluation.

III. Performance Results: Reduced data will be presented and discussed and will include OSCAR readouts from gimbal payloads, acquisition methods and levels, etc.

IV. Summary: In this section the data presented in previous sections will be analyzed as a whole and conclusions will be drawn as to current and expected system performance. Problem areas will be introduced and discussed as will the results of analytical efforts performed on system design logic, effects of the translating platform etc.

V. Recommendations: Those areas of the system in which it is felt, as a result of the evaluation, that further performance improvements are possible will be presented here. These improvements will be within the framework of modifications to the system and not major redesign. Also, areas in which further investigation or evaluation are believed warranted will be pointed out.

4.7 Consideration of a Calibration System for the Downrange Program (H. E. Koritz)

Introduction

Synonymous with the calibration of an instrument is the predictability of its behavior when exposed to a known source of radiation. Implicit in this definition is the precision of this prediction. Consequently, the main function of a calibration system is to provide a quantity (instrument response) with a stated precision. In addition, the calibration system must provide a method for controlling this precision and be capable of calibrating all instruments used in acquiring data.

There are two types of calibration, i.e., quantitative and qualitative. By a quantitative calibration we mean that the results of the calibration will yield a photometric quantity when the output of the detector for an unknown source is compared to the output obtained with a known source. By a qualitative calibration we mean that the results of the calibration will yield information regarding the state of the instrument compared to the state of the instrument at the time of the quantitative calibration. In this report, we concern ourselves with quantitative calibrations only.

Included as an important part of this presentation is a discussion of the response of each type of instrument to radiation, since this understanding is important in determining the equipment and method for providing the instrument with a quantitative calibration, i.e., the "black box" approach to calibration is avoided. From this discussion the calibration problems become evident and the solutions provide calibrator specifications. In addition, this approach avoids the painful, and perhaps impossible, task of determining which calibration is correct when disagreement occurs.

Also discussed are (1) the present calibration scheme, (2) concepts adopted for the proposed calibration scheme, (3) functions of the various parts of the calibration system, (4) the characteristics and response of downrange instruments and their effect on the design of a calibrator, (5) the downrange calibration system, (6) the AERL laboratory calibration system, and (7) a scheme for controlling precision in the calibration system.

Present Calibration Scheme

The present calibration system consists of a variety of on-board and on-site calibration units. The TRAP-7 and TRAP-6 aircraft have on-board calibrators while TRAP-1 aircraft is presently being upgraded and the calibrators for this aircraft are in the design stages. The in-lab calibration unit consists of a 96" focal length bench. Described herein are the various calibration procedures, calibrators, and methods for varying calibrator irradiances. The system as described is shown to consist of a variety of calibrator designs and procedures used in instrument calibration. This is not a desirable feature in that it increases the complexity of comparing calibrations from various aircraft and requires an intimate knowledge of each calibrator. A uniform calibrator and procedure is recommended for the system and because the environmental changes and misalignment can effect calibrations when a source is placed at a distance from the aircraft it is recommended that calibration be accomplished onboard. Also discussed is the relationship between the effect of personnel on calibration results and the method of calibration, and it is suggested that the preferable technique is to perform on-board, in-flight calibrations. The desirability of per mission calibration and the necessity for a primary standard bench is also discussed.

Proposed Calibration Scheme

The proposed calibration scheme presents the philosophy of calibrating the calibration system, maintaining its precision and therefore the precision of the instruments being calibrated, and accomplishing this as systematically and simply as possible.

On the basis of the above discussion, concepts are presented upon which the calibration system procedures and equipment requirements are based. The concepts are enumerated. A few of these are: (1) that calibration equipment design shall be determined by the requirements of simulation of object image relationships encountered downrange, (2) calibrators in the field shall be tied to the AERL standard laboratory by a photomultiplier unit, (3) periodic calibration of downrange instrumentation at the AERL standard laboratory shall be required. In all, twelve concepts are presented.

Functions of the Calibration System

The functions of the in-house calibration laboratory and downrange calibration are defined. For example, two of the functions of the AERL standard laboratory will be to perform precision calibrations routinely and define the limits of acceptable calibration while the primary function of the downrange calibration will be to monitor precision under data taking conditions.

Considerations in Calibrator Design

An important part of the calibration system is a calibrator which can rapidly, and with precision, calibrate the downrange instruments. Since TRAP utilizes a broad matrix of instruments with various dynamic ranges and spectral sensitivities, the specifications of the calibrator must be defined with this in mind. Accordingly, instruments are divided into groups based on their response to radiation. The requirements that their response and other special calibration problems impose on calibrator design is then considered in conjunction with the appropriate approach to be utilized.

The instruments are divided into two groups: (1) those whose calibration with respect to the data obtained downrange is considered well understood and therefore, application of the calibration to the data provides unambiguous results, and (2) those which involve new concepts and for which there is much less experience than with the instruments in the first group. Under group (1), cine cameras, cinespectrographs, K-24 streak spectrographs, radiometers, and ballistic cameras are discussed. Under group (2), the Atomic Line radiometer, Fabry-Perot etalon, the Image Intensifier cinespectrograph, and the Jones High Resolution Telescope are discussed. The calibrator specifications required by each of the instruments are discussed; and once dimensionally defined, the instrument requirements impose conditions on the source system design, i.e., the types of sources and the apertures to be utilized.

The response of cine cameras is discussed in terms of image growth and an empirically arrived at equation, which describes image growth, is presented. In discussing the response of K-24 streak spectrographs, the effects of area images on the determination of the exposure at a point is

considered and it is shown that the relationships used apply only to uniformly exposed areas. The response of radiometers is discussed in terms of their variety of spectrally sensitive surfaces, their linear response, and the requirement for complex electrical equipment to store the data. The meaning of effective bandpass is clarified. The response of cinespectrographs and ballistic cameras is also developed.

The theory of operation of the Atomic-Line Radiometer for the Na. doublet intensity measurement and its ability to measure both continuum and line radiation as well as distinguish between point and distributed sources are discussed. Equations indicating the response of the instrument are presented. A technique for calibrating the Atomic Line Radiometer is presented in which a tungsten lamp and a NaD Source are used.

The Fabry-Perot etalon provides sufficient resolution to determine line shapes and widths by employing a technique of light interference involving multiple reflections. Intensity calibration of the instrument can be provided with a tungsten lamp and the etalon finesse determined by using a sharp atomic line source. These techniques are discussed.

The image intensifier technique provides photon amplification, resulting in approximately a factor of 100 overall increase in sensitivity of the photo-optical system. The response of the instrument and the problems of calibrating a very sensitive spectral instrument with a low temperature black body source is discussed. The calibrator specifications for calibrating the Image Intensifier are given and methods are suggested for calibrating the camera with a high temperature source. These are demagnification and/or low reflectance attenuation.

The Jones High Resolution Telescope is utilized to resolve the re-entry vehicle thus providing information regarding the radiance distribution along the body and the wake. Equations are developed for the exposure at a point of an area source. Calibrator specifications determined by the requirements for calibration of the Jones Telescope are given. Also discussed are the problems associated with interpreting the data for a resolved image which, in addition to being non-uniform is of a conical shape, and possible solutions are suggested. It is suggested that the stagnation point can be treated in a manner similar to the cine growth technique, that spread function experiments can

determine the effects of neighboring regions, and that in regions where the density gradients are small the tungsten lamp calibration can be applied.

By applying the calibration requirements of instruments having unique characteristics such as the Barnes UV Cinespectrograph, the Jones Telescope, the TRAP-6 GSAP No. 1., and the Barnes Optical Tracker, a calibrator is specified. The specifications are given for both a 100" and 250" focal length calibrator. These calibrators could be adopted for either the in-lab or the downrange calibration and would undoubtedly incorporate many features of the TRAP-7, J-216 calibrator. Because apertures required for calibrating the Jones Telescope must produce resolved and partially resolved images, the choice of apertures is discussed on the basis of the image sizes produced in typical trajectories for all TRAP aircraft. Calibrator requirements are presented for all TRAP instruments for a 250" collimator and an f/4 condensing system.

Having developed calibrator requirements, the solution to the problem of determining whether a calibrator is operating properly is obtained by utilizing a photomultiplier unit which has been calibrated at the laborotory. It will be utilized to check the calibrators prior to instrument calibration.

For the AERL standard laboratory, a primary standard irradiance unit is specified for the purpose of calibrating the photomultiplier unit. The present standard in-lab collimator (96" bench) capabilities are the requirement for an additional standard in-lab collimator, perhaps with a 250" focal length, are discussed.

The calibration of auxiliary equipment and the methods for determining the spectral characteristics of all downrange instruments are discussed. A method is suggested for checking the behavior of a calibration system made up of components whose individual spectral characteristics have been determined. The technique involves the use of the photomultiplier unit and the AERL primary standard irradiance unit.

Scheme for Maintaining Precision

Finally, a scheme is proposed for maintaining the calibration system's precision based on the concepts adopted for designing the system, and equipment and calibration procedure recommendations are made for implementing the proposed system. This calibration approach satisfies the requirements

of simulating the object-image relationship encountered in actual data acquisition by the instrument. The calibration system involves two calibrations of each instrument: The first, an in-house calibration, the primary standard of the system, which establishes the behavior of the instrument and the precision index of the calibration, and the second, a downrange calibration, which monitors this precision under downrange conditions.

The use of a photomultiplier unit as the secondary standard of the calibration system has been established to have an important function in maintaining an instrument's calibration precision, and a procedure in which decisions are made on the acceptability of each calibration for the purpose of maintaining the established precision has been arrived at. The concepts adopted for establishing the calibration system govern this procedure for the processing of the downrange calibration data.

The choice of calibrators for the Laboratory and downrange were predicated on the bais of (1) simulation of the object-image relationship downrange, one of the adopted concepts, (2) calibration convenience, (3) stability, (4) simplicity of operation, and (5) versatility. On this basis it was recommended that the downrange calibrator design incorporate many of the features of the TRAP-7 J-216 calibrator. Additional specifications were suggested for the laboratory and downrange calibrators.

Conclusions and Recommendations

On the basis of this report, recommendations for providing a calibration system which has the capability of accurately and rapidly calibrating all TRAP instruments and maintaining their precision are: (1) that all calibrations downrange including IR calibrations be performed on-board, if possible, (2) that all calibrations be performed in flight, where feasible, (3) that provision be made for calibration at an instrument location for instruments which cannot be practically removed from their pedestals, (4) that a single type of calibrator incorporating many of the features of the TRAP-7 J-216 be adopted and that a single calibration procedure for all aircraft be used,

(5) that a photomultiplier unit or other standard sensor be adopted as the secondary standard for the calibration system and be present on each aircraft and at the AERL calibration laboratory, (6) that instruments be regularly rotated back to the AERL calibration laboratory on a yearly basis, if possible, and (7) that all instruments be provided with absolute high precision calibrations in the in-house laboratory and a stated precision index be made for each instrument.

Calibration Equipment

Implicit in the aforementioned recommendations is the requirement for equipment to perform the activities necessary for implementation of the calibration system. They imply the need for the design and construction of additional downrange calibrators; requirements for additional tungsten lamp and black body sources and equipment to operate them; the need for the design and construction of calibrators located at or having the capability of being moved near instruments like the Jones Telescope; the need for photomultiplier units consisting of various detector heads, power supplies and a means for recording the data, and the need for the AERL calibration laboratory to have a primary standard irradiance unit, another standard in-lab collimator in addition to the present 96" focal length collimator and auxiliary equipment-all of which is necessary for providing the large number of TRAP instruments with quantitative calibrations.

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TASK 5.0 INSTRUMENTATION, MAINTENANCE AND SERVICE

J. E. Nunes

Introduction

This task consists of a number of diversified but closely related engineering activities. Specifically included in this area are the design and procurement or fabrication of new instruments and associated peripheral equipment as well as maintenance, repair and upgrading of existing equipment. Included in this section are the significant activities performed within these categories during this reporting period.

Of particular note is the progress on new instruments, systems and equipment in process for use in the TRAP program. Of these, a VIS/IR radiometer, currently under procurement for use on the TRAP-6 aircraft until the gimbal system for the upgraded TRAP-1 aircraft becomes available, an infrared scanning radiometer (REMRAD) which was Government furnished for use on TRAP-6, and a design study on automated microdensitometry are presented herein. Progress in other areas which will be completed under this task, the procurement of an atomic line radiometer and new calibration equipment, is presented under task 4.0 of this report.

It should be noted that of the efforts presented herein, those which have titles preceded by a numerical designation represent contract completion items.

Sustaining Engineering (W. J. Wilson)

During the earlier portion of this reporting period the Engineering Office was reorganized in order to more efficiently perform the various tasks associated with programs of this type. By so doing, it became possible to introduce a number of procedures which allow closer control of the performance of all engineering activities associated with the TRAP program.

Of considerable importance to this task is the effort now known as Sustaining Engineering. This practical concept is the result of experience gained over many years of direct participation in experimental re-entry field

programs of this type. Simply stated, the Sustaining Engineering concept requires the cohesive joining of three basic areas of activity; namely, preventive maintenance, performance analysis and modification.

The foundation of this concept is a sound preventive maintenance program rigorously adhered to in the field and in the Laboratory. Such a program consists of a series of regularly scheduled cleaning, adjustment and performance verification tests and procedures specifically tailored to individual instruments or types of equipment. Erected on this base is a system of equipment performance monitoring and analysis which is carried out by various engineering sections within the Laboratory. Resultant data from this effort not only permits prediction of potential difficulty and allows preventive action to be accomplished, but in addition points up those areas requiring changes in procedures or equipment modification. Individually, each area is important, but closely joined they take on new meaning in terms of optimum overall system performance.

Preventive Maintenance

Sustaining Engineering personnel conduct a technically sound preventive maintenance program for all programs of the TRAP type. This includes the regular review of existing procedures with modification occurring when required. Additional procedures are prepared when necessary due to new or updated equipment. These procedures require the scheduled performance of efforts such as cleaning, adjustment and operation to specification of each system, both primary data collecting and secondary support. These include both field and in-house activities. Detailed records are maintanined with the instrument and any noted deviation in performance is the basis for initiating corrective action. In the case of field activity, duplicate records are sent to the Laboratory for a detailed review and analysis. A maintenance log is used to document repair and maintenance performed in the field and during regularly scheduled rotation of field instruments back to the Laboratory for periodic overhaul and calibration. Data reduction equipment is similarly serviced and maintained in optimum operating condition through a continuing preventive maintenance schedule.

Performance Analysis

Through the Preventive Maintenance Program, there is constant feedback of performance data to the Laboratory. Considerable additional information of this type is received from the data reduction groups in the Laboratory. It is also further supplemented by the results of specific specialized performance tests periodically specified by engineering personnel. Continued analysis of the data from these sources permits the determination of both individual instrument and complete subsystem or system performance. From these results, potential equipment failures can often be prevented and the need for modification predicted.

Modification

The third step in the Sustaining Engineering concept is equipment modification. As indicated in the preceding paragraphs, determination of the need for modification is based on feedback from maintenance and performance analysis activity. This information is further supplemented by personnel contact between engineering and operations personnel, plus on the spot observation and operation of equipment by engineering specialists.

Once the need and type of modification required has been determined, work proceeds immediately to accomplish the task. This is done either completely by engineering or by the original manufacturer under the supervision of Sustaining Engineering personnel. Close attention is paid to mission schedules in order to minimize equipment down time. In many instances, field mod kits are prepared and sent to the field location in order to negate the requirement of returning units to the Laboratory. In those instances when the work involved is extremely complex, engineering personnel go into the field to assist field personnel in performing the tasks at hand.

It should be noted that the approach and methods outlined in the preceding paragraphs is also applied, in every respect, to all in-house data reduction equipment.

Equipment Control

In order to more fully coordinate and control the flow and dissemination of equipment, equipment spares, supplies and performance information, a new section has recently been established within the Engineering Office. This section, known as the Equipment Control Center monitors and coordinates the

flow of all engineering equipment and data to and from the Laboratory and field locations as well as between various areas within the Laboratory. This group maintains a central file of all pertinent maintenance, repair and performance information and ensures distribution of such to appropriate areas for action. Spare parts handling and control also form a major portion of the Center's activity. Detailed records of parts on hand in the field and in the Laboratory are maintained together with individual equipment part usage histories. Such information permits maintaining spares stock at adequate levels at all locations. In addition, centralized control ensures fast response to emergency requirements.

Instrumentation, Maintenance and Service Activities (J. Saulnier)

TRAP-6 Barnes Angular Error Sensor

During May 1967, the TRAP-6 Barnes tracker was returned to AERL. Basic modifications to system performed at that time included addition of a simple, straight-forward, single frequency 850 Hz data good aural tone output signal and the removal of the mixed 232 Hz envelope and 2550 Hz carrier. This will result in less ambiguity for the operator during target acquisition.

Also, the data good pickoff was moved from the raw carrier output to the first stage of the narrow band demodulator, where a bandpass filter was added to give improved selectivity. The data good level adjustment was brought out to the front panel of the control electronics and a day/night switch added, thus enabling the operator to set the threshold level under the varying conditions of a day or night sky background for each mission.

During the second week of June, the tracker was returned to Barnes Engineering and the following trouble areas diagnosed:

a. There was an elevation error signal ambiguity with regard to the locked condition in phase lock loop, which resulted in the random presence of either of two DC elevation voltage levels (approximately 0.3 volts apart) for a given stationary target in the instrument field of view.

b. A misalignment of the phase lock loop in one of the Coherent Detector modules as well as wiring and component differences between the master and spare Coherent Detector Modules.
c. There was excessive mechanical vibration and noise in the reticle motor drive system which resulted in a high amplitude signal at about 10 Hz in the elevation error output, as well as the presence of noisy error signals even with strong targets.
d. The presence of a low frequency beat note on the power supply voltage busses, seemingly related to the frequency difference between the external 400 Hz and the internal precision 400 Hz reticle motor supply.
e. Sensitivity in one of the Coherent Detectors in the phase lock loop "locked" condition with regard to AC line input voltage variations. The loop lost "lock" at a line voltage condition of between 119 V and 122 V, which resulted in the generation of erroneous azimuth and elevation output signals in that range.

In that process of several days of intensive bench testing, the following repairs were effected in the following areas:

a. Error Signal Output Ambiguity and Phase Lock Loop: Although the ambiguity of approximately 0.3V peak to peak still remains in the elevation channel error output with regard to a fixed target position in the FOV, it has been minimized by means of phase lock loop adjustments to the point where it is insignificant in wide FOV mode. The ambiguity was found to be inherent in the circuit design and not removable unless the phase lock loop, envelope phase detector and polarity sensing circuits are redesigned. Also, the differences in the circuit parameters between the two coherent detector modules were corrected and the two modules are now interchangeable with no noticeable differences in system operation. With respect to the line voltage effect

on the coherent detector, this situation was corrected by reducing the phase lock loop error gain to a value much more consistent with the spare module.

b. Reticle Wheel Motor and Drive System: Excessive vibration in the gear reduction and/or thrust bearings was found to be responsible for noise and the large 10Hz component contained in the error outputs. By applying small amounts of manual "drag" to the reticle wheel, the 10Hz component could be made to disappear altogether. The spare reticle drive sub-assembly was installed and functioned satisfactorily causing a reduction of 10 to 20 db in the 10Hz component. The faulty reticle drive assembly was left at Barnes Engineering for repairs and realignment.

c. Optics: The primary mirror was cleaned and the boresight shift between wide and narrow FOV was investigated. It was found to be approximately 0.5 milliradian in both azimuth and elevation. Although the original specification calls for a maximum of 0.1 milliradian boresight shift in either axis, it was felt that due to schedule limitations, it was not advisable to attempt to adjust the narrow FOV secondary mirror.

TRAP-6 35mm High Resolution Camera (M.H. Gurley)

The Jones 80" F.L. High Resolution camera system was returned to AERL in April for realignment of its optical system due to apparent loss of its maximum resolution capability while in field use on the TRAP-6 aircraft. The camera support platform was removed from the back of the lens and the lens secured on the 96" F.L. optical bench for inspection. The image of a 0.0015" point source was examined with a microscope and confirmed a misalignment of the optical system. Consequently, the optical system was disassembled for inspection and realignment. The primary mirror was cleaned and reset in position and the optical system realigned using a laser and the collimated beam of the optical bench.

Due to the tight turn around schedule which had to be met, a detailed analysis of the cause of the poor image was not undertaken. It did appear, however, that the secondary mirror was the element that had moved. After realignment, both static and dynamic tests indicated that the instrument was providing 50 lines/mm (2 arc seconds) resolution.

TRAP Transportable (W. J. Wilson)

The following maintenance and data assurance items were performed during reporting period to the TRAP-Transportable ground station, in addition to the routine servicing functions normally performed to the system on its return to AERL between missions:

a. The primary power for the system has been supplied by two 28VDC aircraft type batteries. As the problems associated with the transportation of these lead-acid type batteries are numerous and since 115 VAC, 60 Hz power is available at all site locations, two 28 VDC Electronic Research Associates Model F28/40 power supplies have been procured. These power supplies were packaged such that they can be used as a direct replacement for the batteries. Where feasible, the batteries will be maintained as backup in case of power supply failure.

b. Unless extreme care was taken in settling the level control on the Ampex 601 tape recorder, the main time comb (MTC) signal would saturate the recorder. This condition arose because the 10KHz carrier, which is modulated at the MTC rate, was at the edge of pass band of the Amplex tape recorder. To correct this situation, a circuit has been designed and installed in the Camera Control Unit which changes the carrier frequency from 10KHz to 5 KHz. This now allows a broad range of level control setting to be utilized and has alleviated recording and reduction difficulties.

Vis/IR Radiometer (P. D. Howes)

Introduction

As reported in the last Semi-annual Report, a dual-channel VIS/IR radiometer is under procurement from Barnes Engineering Company. This radiometer employs an S-20 photomultiplier tube as a sensor in the visible channel and a thermoelectrically cooled PbS detector in the IR channel. Field interchangeable filters are utilized which are located just in front of

the detectors. The specifications, optical diagram, and signal processing block diagram are presented in table I- 6, figure I-16, and figure I-17 by way of summary.

Status

Delivery of the radiometer is being delayed due to considerable problems encountered by Barnes Engineering in obtaining the cooled PbS detector. These delays have been caused by a detector failure and numerous vacuum seal problems. A second detector is available for use, although having twice the active area as that required for this instrument. This alternate detector is being tested to determine if it has sufficient sensitivity to pass the acceptance criterion. If the proper detector delivery cannot be accomplished within a reasonable time from that when the substitute detector becomes available, the substitute will be employed. Procurement of the correct detector will continue however, and if the sensitivity to be gained by employing this detector is adequate, an interchange will be accomplished at the earliest time possible. At this writing, acceptance and delivery of the radiometer is scheduled to occur in July.

Filters

The characteristics of the filters procured for use with the instrument are shown in table I- 7. On acceptance and delivery to AERL, the instrument will be calibrated with all filters prior to installation on the TRAP- 6 aircraft.

Re-entry Monitoring Radiometer (REMRAD) (W. J. Wilson)

Introduction

In accordance with the amendment to task 5.0 specified by CCN #1 to the basic contract, engineering group proceeded with the initial phases of operational evaluation of the REMRAD. This instrument, together with an Ampex AR-214 tape recorder system, was received as GFP at AERL during the week of 17 April 1967.

Instrument Description

The Re-entry Monitoring Radiometer (REMRAD) was designed to provide resolution scanning in four infrared spectral bands from 2.5 microns to 5.5 microns with interchangeable spectral filters. The resultant video data presents spatially resolved radiometric information in four selectable spectral regions.

TABLE I-6

TWO-COLOR RADIOMETER

Optical Unit:

Collecting Aperture Diameter	8"
Effective Aperture	140 cm^2
E. F. L.	40"
Geometric F/#	F/5
Effective F/#	F/8
Field of View	1° or $1/2^\circ$
Background Suppression	300: 1 (min)
Chopping Frequency	730 cps

	Visible	IR
Detector	S-20	PbS (cooled)
Anticipated Sensitivity	8×10^{-17} (w/cm^2)	8×10^{-14}(w/cm^2)

Typical Response Profile:

Response	1%	10%	50%
PM	1μ, 3.4μ	1.2μ, 3.1μ	1.75μ, 2.75μ
PbS	0.77μ	0.71μ	0.37μ, 0.56μ

TABLE I-7

TWO-COLOR RADIOMETER FILTER SPECIFICATIONS

PM Channel

A	3300 A ± 300 A
B	3860 A ± 40 A
C	6132 A ± 10 A

PbS Channel

A	1.0 - 2.0μ (blocked < 1.0μ, > 2.2μ)
B	2.29 - 2.5μ (blocked < 2.2μ, > 2.6μ)

OPTICAL DIAGRAM

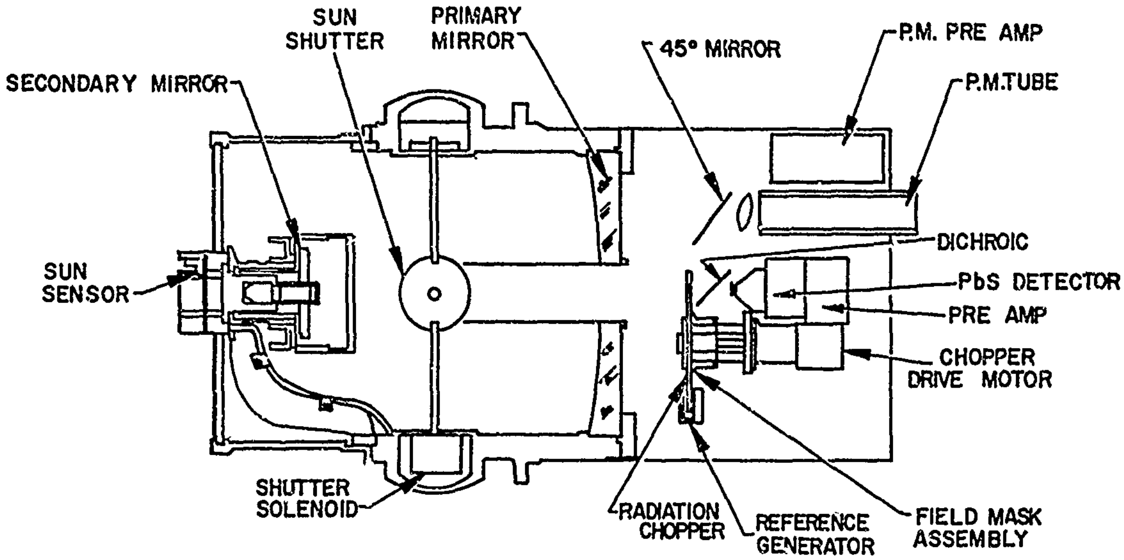


Fig. I-16 Optical diagram for two-color radiometer.

ELECTRONIC SIGNAL PROCESSING BLOCK DIAGRAM TWO COLOR RADIOMETER

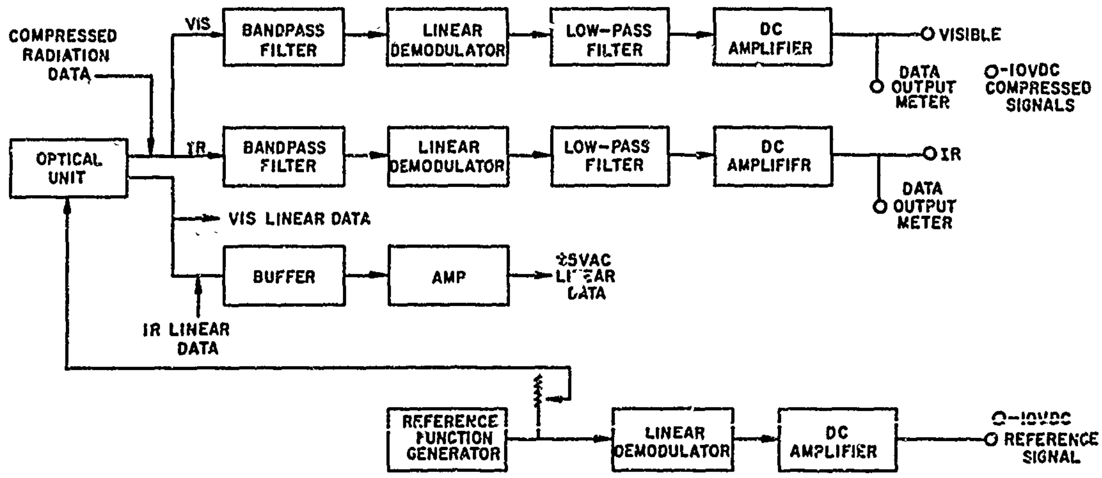


Fig. I-17 Electronic signal processing block diagram for two-color radiometer.

R-6917
R-6918

The instrument consists of two units, an infrared optical scanner assembly, and an electronic unit. The optical scanner subassemblies are the gimbaled mechanical scanner, the video preamplifiers and line amplifiers, a four level reference calibration subassembly, plus an open cycle liquid nitrogen cryogenic.

The optical scanner mechanically searches a field of 15 degrees in azimuth by 3 degrees in elevation four times per revolution of the scanning rotor. The azimuth scan is accomplished by four refractive optics mounted in quadrants on the rotor, such that each of the four optics pass the detector array once in each revolution.

The elevation field (3^{o}) is defined by a five element grown junction indium antimonide linear detector array which subdivides this field into 0.6 degree sectors. Simultaneous video data is obtained from the five channels scanning the 15 degree azimuth field of view.

The detector array is mounted on the axis of the scanning rotor with a window appropriate for the optical search. The array is cooled by liquid nitrogen (77^{o}K) transferred from a storage dewar by a two phase system where the liquid travels in balls surrounded by nitrogen gas (2 phases) through a tube from the storage to detector dewar.

The scanner electronics consist of five wide band, wide dynamic range preamplifiers mounted around the end of the detector dewar. The signals from the preamplifiers pass to five line amplifiers which provide controlled gain plus electrical filtering. These amplifiers are mounted on the rear of the scanner for ease of access to the trim adjustments.

A four-level radiometric reference calibration is introduced into the scanner by an imaged filament source whose output is injected into each optic during the dead scan time of each optical quadrant.

The electronic unit consists of three chassis suitable for standard 19 inch rack mounting. They are: the electronic control assembly consisting of plug-in printed circuit cards, the power supply/control panel assembly and the voltage controlled oscillator assembly. Except for the voltage controlled oscillator assembly, the electronics are completely transistorized.

The electronic control assembly has three main functions: (a) Control the gains in the five signal channels to insure that signal amplitudes up to 100 db signal to noise ratio remain within the dynamic range of the amplitude modulation tape recorder. The gain changes are made once per each scanner revolution in a dead scan based upon sampling of the outputs of the previous frame and results in linear recording with a 100 db dynamic range. (b) The electronic timing of the video sampling period (15° AZ), the gain adjustment period, and the gated azimuth vernier are also accomplished in the electronic control assembly. Position reference pins on the scanner rotor and sensing magnetic pick-ups result in the generation of pulses which activate logic circuits to determine the desired timing characteristics. (c) The azimuth position is generated in this assembly by circuitry which phase locks a high frequency oscillator to a lower frequency representing the rotor speed. The rotor positional representation is generated by a type of magnetic encoder. The higher frequency phase locked azimuth vernier is gated for an output only during the 15° of scan.

The power supply/control panel assembly provides a central unit for the necessary system power and control functions. The control front panel has switches for such functions as: main power, heaters, calibration lamp spin motor, heaters and calibrate plus indicator lights for video levels and cryogenic conditions.

The voltage controlled oscillator (VCO) assembly is a unit used to encode the gain setting conditions in each of the video channels. There is a VCO for each of the five video channels and one for the calibrate unit which encode by frequency shifts the attenuator settings. All of the channels are mixed and can be placed on one tape track.

System design specifications are listed in table I- 8.

TABLE I-8
REMRAD DESIGN SPECIFICATIONS

Scanning Characteristics	
Sensitivity: Noise Equivalent Flux Density	5×10^{-12} at 4.7μ
Total Search Field	3^{o}EL x 15^{o}AZ
Field Rate	40 scans/sec
Frame Rate (4 spectral regions)	10/sec
Instantaneous Field of View	0.02^{o}AZ x 0.6^{o}EL
Spectral Region	2.5 to 5.5μ
Spectral Filters	a) 2.825 to 4.225μ
λ_c - center wavelength - microns	b) $\lambda_c = 4.49\mu$, BW = $.175\mu$
BW - bandwidth - microns	c) $\lambda_c = 4.8\mu$, BW = $.325\mu$
	d) $\lambda_c = 5.26\mu$, BW = $.425\mu$
Signal Processing	
Video: 5 channels Linear Processing	
Dynamic Range	100 db
Electrical Bandwidth (3db)	100 kHz
Gain (Nominal)	40 db
Position: Azimuth Vernier	$\pm .02^{o}$
Elevation (Individual Detectors)	$\pm 0.3^{o}$
Calibration Relative Reference: Drift for mission	
Input Levels	4
Control Signals	
Target Indication - Channels	5
20, 40, 60 db Attenuators Channels	5
Cryogenics	
Open Cycle - Liquid Nitrogen, 2 Phase Delivery, 2.4 liter storage	
Electrical Requirements	
Volt-Amperes	400
Frequency	400 Hz Single Phase
Physical Characteristics	
Scanner: Weight	85 lbs.
Dimensions	13" dia. x 25" long
Electronic Unit: Weight	50 lbs.
Dimensions	19" wide x 34" high

Laboratory Evaluation

Effort was immediately applied to equipment inspection and familiarization. The radiometer itself was found to be in acceptable condition, and in general, in-lab attempts to duplicate data taken during acceptance tests were successful. As received, however, the Ampex recorder wa in relatively poor condition and as a result major refurbishment by the manufacturer was required.

The recorder was returned to the Ampex Service Company in New Jersey on 1 May 1967 with work scheduled for completion by the end of June. Due to the age and condition of the unit the overhaul required proved to be considerably more extensive than originally anticipated. The work performed included: rebuilding of the reel and capstan drive motor; complete refurbishment of the record head, rebuilding of the capstan flywheel assembly, adaptation and installation of shock mounts plus replacement of numerous electrical and mechanical components. Lack of availability of replacement parts and depth of refurbishment required will delay return of the unit to AERL until the week of 17 July.

During the interim, work on the basic radiometer was completed in the Laboratory. This included complete instrument evaluation and calibration, and the design and fabrication of a mount to allow field installation of the unit on Manual Pedestal T-2 at the rear cargo door of the TRAP 6 aircraft.

During the course of the in-lab evaluation, preliminary results indicated that in order to achieve low level target measurements, it would be necessary to operate the instrument with the attenuator disabled. Consequently, field techniques were established to utilize such a mode of operation. The design of the REMRAD is such that detector dimensions project to 115 ft x 3450 ft in object space at 10^7 cm slant range (one detector). Assuming a re-entry complex 1000 ft x 3 ft in dimensions, alignment of the complex in parallel with the detector array means that the re-entry complex is only about 1/3 the length of one of the detectors. With the REMRAD oriented as designed, i.e., with the detector array aligned vertically, the largest angle between detector array and complex that can be expected is 45°. At this angle the vertical projection of the re-entry complex model covers 707 feet which is about one-fifth the detector length (single detector). Thus it is to be

expected that the re-entry complex will usually illuminate only a portion of one detector at a time. The attenuator logic for a detector is actuated once per revolution of the scanner on the basis of the highest signal recorded for any of the four telescopes (usually scope #3 because of its broad spectral bandpass). We assume further that the first 100 ft of re-entry complex provides 100 times the intensity of the following 100 ft.

The 0 db gain setting provides less than 40 db dynamic range (80 mv to 2.1) while the other gain settings provide, in conjunction with the tape recorder, exactly 40 db. That is, given two signals such that the one of the higher amplitude is just below the upper threshold at a particular gain setting, the tape recorder will record signals 40 db down from that level. With the given model however, the wake signal would then be in the noise. Thus, if the dimmer signal can be seen the first time around, the brighter signal will be large enough to actuate an attenuator for the second revolution. If the brighter signal does not now exceed the high threshold for one of the gain settings, the dimmer signal will be in the noise. Removal of the attenuators will allow reduction of wake data ranging between 4×10^3 and 4×10^5 watts/ster per resolution element (115 ft) at 10^7 cm slant range (telescope #3). The lower number is dictated by sensitivity, the dynamic range is imposed by the tape recorder.

The data recording and data reduction concept involves: a) magnetic tape recording (5 video channels, 1 azimuth position channel, and 1 timing channel), b) playback and display on an oscilloscope in-lab, c) cine film recording of the oscilloscope display during selected time intervals of the data, and d) highly selected manual amplitude measurements to obtain intensities.

As of this writing, work on the basic instrument has been completed and we are awaiting the return of the tape recorder. Upon receipt, the two units will be mated, checked and calibrated and the system will be shipped to the field for installation. Installation drawings and instructions have been prepared and self pressurizing dewars for the liquid nitrogen supply procured. Arrangements have been made to have liquid nitrogen available at the various operating locations. It is anticipated that field installation will occur during the first week of August 1967 dependent upon aircraft location and availability.

It is planned that the REMRAD system will be operated against targets during the months of August through October of this year. Analysis of data and evaluation of instrument performance will commence immediately following the first operational mission and continue through December. A report covering instrument performance and recommendations for future utilization will be issued upon completion of the evaluation.

Digital Microdensitometer

Introduction

Several forms of photographic re-entry data may be analyzed by use of reduction techniques utilizing microdensitometers. Of these, spectral records and high resolution photographs are the prime sources of information most applicable to this data reduction approach. Both types of data essentially require the retrieval of photometric information which must be known in relationship to its position on the film. Each of these quantities must be known to a high degree of precision. The use of a microdensitometer provides the means for obtaining this information. The information content of both types of data (spectral and high resolution) is such that many line scans per data frame are required for the transfer into meaningful format. AERL presently utilizes three microdensitometers in the reduction of such data. One of these, a GAF Model 652, has the necessary characteristics to provide correlated positional (x, y) and densitometric (density) information and as such can be interfaced with automation equipment to provide automatic preselected scans with on-line analog to digital conversion.

The Requirement for Automation

The requirement for automated microdensitometry arises from two considerations. The first of these is the basic nature of the data in that each film possesses in the order of 10^5 useful pieces of information per square cm of exposed area. At the present time, only analog methods are available to reduce this data. Limitations in analog recorder bandwidth and manual operation of chart digitizers are the pacing factors in the reduction of such data. These techniques do provide useful intensity data from spectral records, but if one desires to analyze the details of high quality spectrograms such as are available from Barnes cinespectrographs at a rate commensurate with the resolution of the data, the use of manually operated digitizers not

only introduces excessive time lags but also limits the accuracy with which the data can be reduced. This latter limitation is even more apparent in the case of detailed raster scans of high resolution images which require precise correlation of multiple scans. In this case manual chart digitizing would be highly impractical, if not impossible, as a means to obtain useful analytical outputs. It is because of the high data content that on-line analog to digital conversion is necessary.

The second consideration is also related to the high information content of the raw data. Once the data has been digitized the resulting digital information can be so extensive that inordinately long computer runs are required. In the case of spectral data in particular, detailed high resolution scanning is desirable when looking at band or line radiation, but not in the case of the background continuum which usually represents the predominant amount of data. It is also desirable to be able to select positional limits for each data scan. With these concepts in mind, in addition to on-line analog to digital conversion, provisions for variable digital sampling rates and a programmable scan position would result in a marked increase in efficiency in the use of the overall system.

The desired benefit accruing from an automated microdensitometric facility is an increase in the speed with which data can be reduced for absolute intensities. Such a system would increase the amount of data which can be reduced.

Table I- 9 illustrates this point for streak spectrograph data. * With a nonautomated microdensitometer the stage must be run at a relatively slow rate (typically 10mm/min to prevent the data from exceeding the frequency response limitations of the chart recorder. The charts must be digitized by means of a manual reader, which requires approximately 10 minutes per scan. With an automated microdensitometer the stage is run at full speed (50mm ~min in the case of the GAF) and digitization is automatic. It is assumed in both cases that one scan is taken per 0.1 second of mission time, i.e., ~15 scans per frame. There are typically 5 frames of data per camera

*The streak spectrographs records in a 4 x 5 format, framing approximately every 2 seconds with a framing time of ~0.4 seconds.

per mission. The tabulated scanning times include time for step-overs between scans, and logging relevant information, and as a result are not proportional to stage speeds.

TABLE I - 9

DATA PROCESSING COMPARISON

	Set-up (min)	Scan (min)	Digitize (min)	Total Per Frame (hr)	Total Per Camera (hr)
Auto.	5 (1000 pps)	15	0	1/3	1-2/3
Nonauto	5 (30 pps)	60	150	3-1/2	17-1/2

An equally important difference between the analog microdensitometer and an automated facility lies in the amount of data retrieved per scan. Normally 30-50 data points per scan are digitized on the Gerber reader,[1] and from these, crude line and band intensities as well as continuum intensities may be derived. To obtain improved line and band data the film must be rescanned at a slower rate on the microdensitometer to obtain expanded chart records which must then be digitized on the Gerber reader. The extra time and labor involved in this process is so great as to make accurate reduction of line and band data on a routine basis impractical. This is a particularly significant loss to the TRAP program in view of available Barnes cinespectrograph records which are capable of recording high quality emission spectra. A wideband digital microdensitometer can record as many points per scan as may be desired. However, if the sampling rate were constant, it would typically be necessary to record approximately 20,000 points per scan in order to avoid degrading the details of molecular and line spectra. To avoid computer overload, a programmable variable sampling rate is highly essential to sustain an efficient through-put of the

1. "TRAP Data Reduction Procedures, Addendum to Semi-Annual Program Progress Report, Re-entry Measurements and Analysis for the Terminal Radiation Program (TRAP)," Contracts AF 04(694)-452 and AF 04(694)-623, July 1965. SECRET

digitized information. In this case, one can automatically digitize all of the significant data on the film in approximately 1000 points per scan for a K-24 record, thereby making it feasible to reduce large quantities of line and band intensity data, as well as continuum data, on a routine basis. Thus, an automated microdensitometric capability would simultaneously bring about a large reduction in microdensitometry time per frame and considerably increase the amount of data retrieved from each frame.

With regard to Barnes cinespectrograph data, an automated microdensitometer can accomplish two tasks which are not practical with an analog system. First, if the densitometer has sufficiently high optical resolution and positional accuracy, it is practical to do two-dimensional integration of the data to obtain accurate intensities. (This involves raster scanning of each frame with a step-over of a few microns. Only relatively crude intensity data can be derived from a single scan per frame.) Second, cinespectrograms which are curved due to camera distortion can be reduced as readily as undistorted spectra by a similar raster-scan technique.

System Configuration

A system configuration to accept spectrographs from the AERL GAF Model 652 densitometer is being developed and a report is in preparation. In this report, present manual data reduction procedures are described and necessary functions to be performed are delineated; performance specifications for an automated facility (computer-based) are developed and an instrumentation model is formulated which is to be exercised in real time. Also, an error analysis is provided to show control system conformance to performance specifications. Computer I/O requirements are prescribed which will completely satisfy the necessary man-machine functions which were developed from the present manual operation.

A block diagram of the hardware concept is presented in figure I-18.

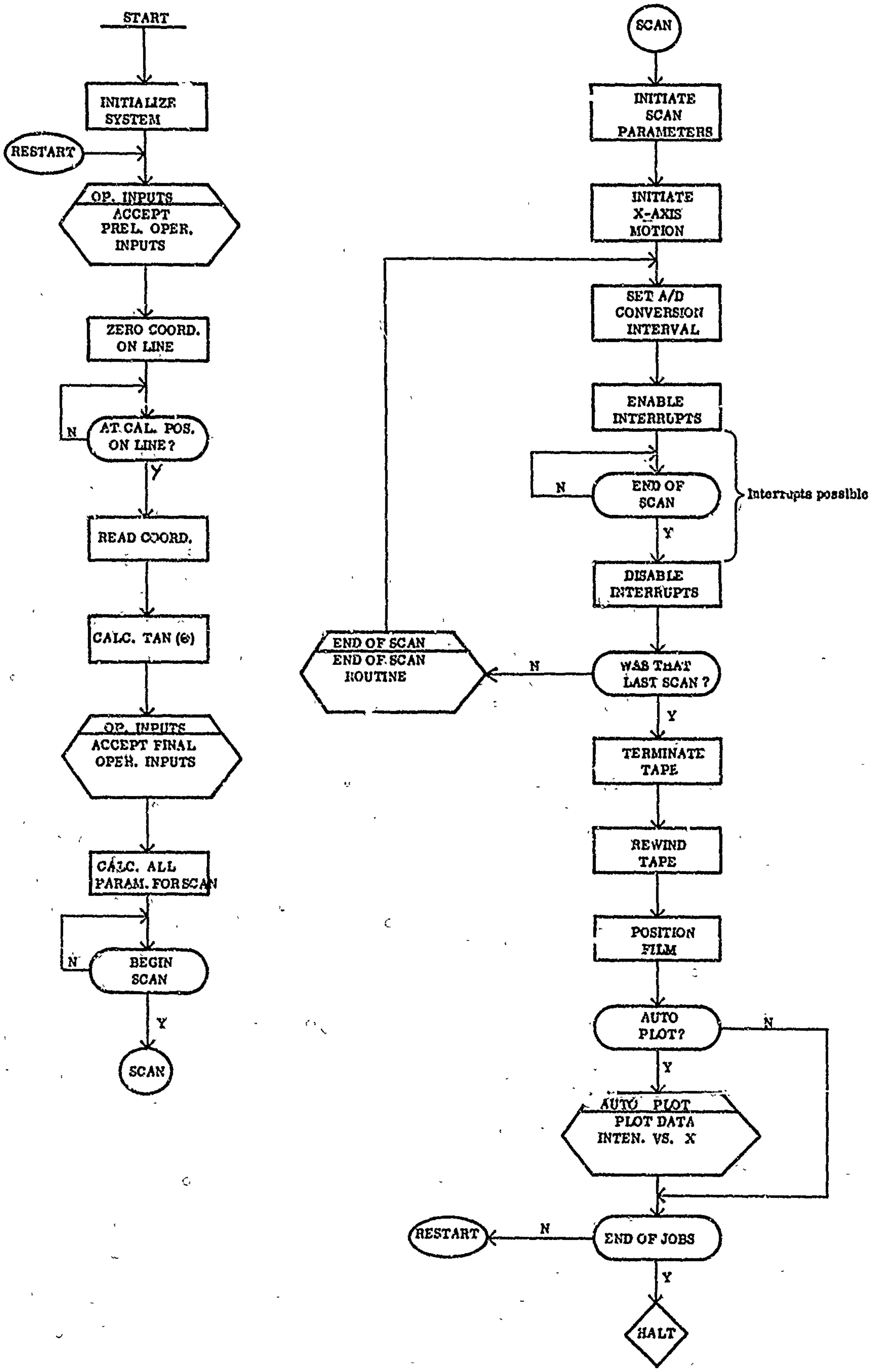


Fig. I-18 Automated microdensitometer, preliminary block diagram.

TABLE I-10

INSTRUMENT	DESIGNATION	LOCATION	SPECIAL PROVISIONS	COLLECTOR FOCAL LENGTH - f#	FIELD OF VIEW VERT. AND HORIZONTAL	NORMAL SAMPLING RATE	FILM TYPES	SPECTRAL RANGE	SPECTRAL RESOLUTION
FIXED INSTRUMENTS									
TWIN "NODDING" BALLISTIC CAMERA	BAL.#1 & #2 FID. #27 & #28	P-4 WINDOW	ROTATES DOWNWARD TO STRETCH OUT STAR TRACES. BINARY CODED CHOPPING	METROGON 6" - f/6.3	$80^\circ \times 114^\circ$	1-4 CHOPS/SEC PULSE WIDTH CODED	RXP 8 x 10 SHEET	.39 - .65 μ	N A
WILD/AERL "NODDING" BALLISTIC CAMERA	AVIOGON FID. #297	P-2 WINDOW	ROTATES DOWNWARD TO STRETCH OUT STAR TRACES. BINARY CODED CHOPPING	UNIVERSAL AVIOGON 6" - f/5.6	$74^\circ \times 74^\circ$	1-4 CHOPS/SEC. PULSE WIDTH CODED	TYPE 018 9 1/2" x 10 1/2" GLASS PLATE	.39 - .7μ	N A
SUPER STAR CAMERA	K-24 #3 FID. #105	P-5 WINDOW	1/4 - SECOND CHOPPING	AERO-EKTAR 12" - f/2.5	$24^\circ \times 24^\circ$	2 SEC/FRAME	2475 REC. 5 1/2"x 56' ROLL	.39 - .7 μ	N A
SUPER STAR CAMERA	K-24 #4 FID. #125	P-5 WINDOW	1/4 - SECOND CHOPPING	AERO-EKTAR 12" - f/2.5	$24^\circ \times 24^\circ$	2 SEC/FRAME	2475 REC. 5 1/2"x 56' ROLL	.39 - .7 μ	N A
BIOGON CAMERA	K-24 #5 FID. #24	P 6-1 INSTRUMENT PLATFORM AT OPEN DOOR	SINGLE FRAME WIDE-ANGLE VIEW; UNCHOPPED	BIOGON 3" - f/4.5	$80^\circ \times 80^\circ$	NOT PULSED	2475 REC 5 1/2"x 56' ROLL	.39 - .7 μ	N A
IMAGE MOTION COMPENSATION CAMERA	IMC K-46	P-1 WINDOW	PROGRAMMED FILM MOVEMENT TO COMPENSATE FOR TARGET IMAGE MOTION DURING LONG EXPOSURES.	AERO-EKTAR 7" - f/2.5	$39^\circ \times 39^\circ$	2 SEC/FRAME	2475 REC. 5 1/2" x 56' ROLL	.39 - .7 μ	N A
METEOR SPECTROGRAPH	K-24 #1 FID. #7	P-3 WINDOW	GRATING: HIGH DISPERSION 600 LINES/MM 5500A BLAZE	AERO-EKTAR 7" - f/2.5	$39^\circ \times 39^\circ$	2 SEC/FRAME	2475 REC. 5 1/2" x 56' ROLL	.39 - .7 μ	4A
METEOR SPECTROGRAPH	K-24 #2 FID. #11A	P-3 WINDOW	GRATING: HIGH DISPERSION 300 LINES/MM 6000A BLAZE	AERO-EKTAR 7" - f/2.5	$39^\circ \times 39^\circ$	2 SEC/FRAME	2475 REC. 5 1/2" x 56' ROLL	.39 - .7 μ	4A
U. V. METEOR SPECTROGRAPH	K-24 #7 FID. #84	P 6-4 INSTRUMENT PLATFORM AT OPEN DOOR	GRATING: 300 LINES/MM 3600A BLAZE COASTING MOUNT PROVIDES COVERAGE OF ENTIRE TRAJECTORY.	HILGER & WATTS 8" - f/3.5	$35^\circ \times 35^\circ$ (SEE SPECIAL PROVISIONS)	2 SEC/FRAME	2475 REC. 5 1/2" x 56' ROLL	.3 - .7 μ	10A
I. R. METEOR SPECTROGRAPH	K-24 #6 FID. #15A	P 6-2 INSTRUMENT PLATFORM AT OPEN DOOR	GRATING: 300 LINES/MM 6000A BLAZE CORNING K-2 FILTER	AERO-EKTAR 7" - f/2.5 FOCUSSED AT 8000 Å	$39^\circ \times 39^\circ$	2 SEC/FRAME	I.R. 5 1/2" x 56' ROLL	.6 - .9 μ	8A
TRACKING INSTRUMENTS									
MK IIA RADIOMETER	CHANNEL 1	P6-3 SLAVE GIMBAL #2 AT OPEN DOOR	S-20 PHOTO MULTIPLIER 5730 FILTER	BINOCULAR OBJECTIVE 7" - f/3.5	$1.5^\circ \times 1.5^\circ$	800 C.P.S.	RECORDED ON TAPE	.5726 - .5739 μ	N.A.
	CHANNEL 2	P6-3 SLAVE GIMBAL #2 AT OPEN DOOR	S-20 PHOTO MULTIPLIER 5893 FILTER	BINOCULAR OBJECTIVE 7" - f/3.5	$1.5^\circ \times 1.5^\circ$	800 C.P.S.	RECORDED ON TAPE	.5887 - .5900 μ	N.A
MK IIB RADIOMETER	CHANNEL 1	P6-3 SLAVE GIMBAL #2 AT OPEN DOOR	Ge DETECTOR Si FILTER	BINOCULAR OBJECTIVE 7" - f/3.5	$1.5^\circ \times 1.5^\circ$	1200 C.P.S.	RECORDED ON TAPE	1.13 - 1.72 μ	N.A.
	CHANNEL 2	P6-3 SLAVE GIMBAL #2 AT OPEN DOOR	PbS DETECTOR Ge FILTER	QUARTZ OBJECTIVE 7" - f/3.5	$1.5^\circ \times 1.5^\circ$	1200 C.P.S.	RECORDED ON TAPE	1.77 - 2.25 μ	N.A.

NOTE: IN GENERAL, INSTRUMENTS ARE SUBJECT TO CHANGE BY MODIFICATION OR REPLACEMENT. LENSES, LENS SETTINGS, FILTERS, FILM TYPES, ETC. ARE ESPECIALLY SUBJECT TO CHANGE DEPENDING UPON THE REQUIREMENTS OF THE PARTICULAR TEST TO BE MONITORED. REFER TO DATA SUPPLIES PUBLISHED IN THE RE-ENTRY DATA REPORTS FOR ACTUAL INSTRUMENTATION EMPLOYED FOR EACH TEST.

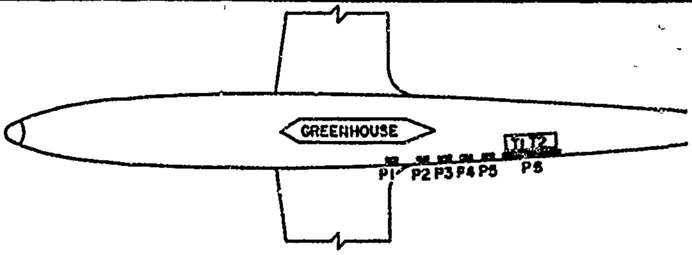
FOR IDENTIFICATION OF POSITIONS SUCH AS P-1, ETC., REFER TO SKETCH OF AIRCRAFT.

A

TABLE I-10

FILM TYPES	SPECTRAL RANGE	SPECTRAL RESOLUTION	MINIMUM DETECTABLE IRRADIANCE	SPATIAL RESOLUTION	DYNAMIC RANGE	TYPE OF DATA	DATA APPLICATION	REMARKS
RXP 8 x 10 SHEET	.39 - .65 μ	N.A.	6×10^{-13} WATTS/CM^2	1 M.R.	--	POSITION OF OBJECTS; TIME; LUMINOUS INTENSITY	TRAJECTORIES; OBJECT IDENTIFICATION; INTENSITY PROFILE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE.
TYPE 018 9 1/2" x 10 1/2" GLASS PLATE	.39 - .7μ	N.A.	5×10^{-13} WATTS/CM^2	0.1 M.R.	--	POSITION OF OBJECTS; TIME; LUMINOUS INTENSITY	TRAJECTORIES; OBJECT IDENTIFICATION INTENSITY PROFILE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE. UTILIZES GLASS PLATE FOR INCREASED ACCURACY.
2475 REC. 5 1/2"x 56' ROLL	.39 - .7μ	N.A.	2×10^{-14} WATTS/CM^2	0.2 M.R.	--	POSITION OF OBJECTS; TIME; LUMINOUS INTENSITY	TRAJECTORIES; OBJECT IDENTIFICATION; INTENSITY PROFILE	GREATER SENSITIVITY FOR LOW INTENSITY OBJECTS.
2475 REC. 5 1/2"x 56' ROLL	.39 - .7μ	N.A.	2×10^{-14} WATTS/CM^2	0.2 M.R.	--	POSITION OF OBJECTS; TIME; LUMINOUS INTENSITY	TRAJECTORIES; OBJECT IDENTIFICATION; INTENSITY PROFILE	GREATER SENSITIVITY FOR LOW INTENSITY OBJECTS.
2475 REC 5 1/2"x 56' ROLL	.39 - .7 μ	N.A.	5×10^{-13} WATTS/CM^2	1 M.R.	--	LUMINOUS INTENSITY; ALL EVENTS RECORDED	INTENSITY PROFILE	PROVIDES USEFUL QUALITATIVE RECORD OF RE-ENTRY.
2475 REC. 5 1/2" x 56' ROLL	.39 - .7μ	N.A.	4×10^{-14} WATTS/CM^2	1 M.R.	--	LOW-LEVEL LUMINOUS INTENSITY	LOW INTENSITY TARGET DATA	SENSITIVITY DEPENDS ON TARGET IMAGE RATE.
2475 REC. 5 1/2" x 56' ROLL	.39 - .7μ	4A	4×10^{-11} W/CM^2-μ AT BLAZE 4×10^{-14} W/CM^2 WITHOUT GRATING	1 M.R.	-- --	SPECTRUM INTEGRATED OVER TARGET AND TRAIL	SPECIE IDENTIFICATION; TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE.
2475 REC. 5 1/2" x 56' ROLL	.39 - .7μ	4A	4×10^{-11} W/CM^2 -μ AT BLAZE 4×10^{-14} W/CM^2 WITHOUT GRATING	1 M.R.	--	SPECTRUM INTEGRATED OVER TARGET AND TRAIL	SPECIE IDENTIFICATION; TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE.
2475 REC. 5 1/2" x 56' ROLL	.3 - .7μ	10A	7×10^{-11} W/CM^2-μ AT BLAZE 4×10^{-13} W/CM^2 WITHOUT GRATING (.3 - .4μ) (FILTERED)	1 M.R.	--	SPECTRUM INTEGRATED OVER TARGET AND TRAIL. U.V. AND VISIBLE	SPECIE IDENTIFICATION; TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE.
I.R 5 1/2" x 56' ROLL	.6 - .9μ	.8A	6×10^{-9} W/CM^2-μ AT BLAZE	1 M.R.	--	SPECTRUM INTEGRATED OVER TARGET AND TRAIL	SPECIE IDENTIFICATION; TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE.
RECORDED ON TAPE	.5726 - .5739 μ	N.A	5×10^{-13} WATTS/CM^2 - μ	N.A.	10^6	INTENSITY VS TIME FOR SELECTED WAVELENGTH BANDS	SPECTRAL CHARACTERISTICS	
RECORDED ON TAPE	.5887 - .5900μ	N.A.	7×10^{-13} WATTS/CM^2 - μ	N.A.	10^6	INTENSITY VS TIME FOR SELECTED WAVELENGTH BANDS	SPECTRAL CHARACTERISTICS	BOTH ANODE AND DYNODE SIGNALS OF THE MK IIA RECORDED. DYNODE SIGNAL OF EACH MK IIA CHANNEL MULTIPLEXED WITH MK IIB SIGNAL OF CORRESPONDING CHANNEL.
RECORDED ON TAPE	1.13 - 1.72 μ	N.A.	2×10^{-11} WATTS/CM^2 - μ	N.A.	10^4	INTENSITY VS TIME IN THE I.R.	SPECTRAL CHARACTERISTICS	
RECORDED ON TAPE	1.77 - 2.25 μ	N.A.	6×10^{-11} WATTS/CM^2 μ	N.A.	10^4	INTENSITY VS TIME IN THE I.R.	SPECTRAL CHARACTERISTICS	

AT 10 MM/SEC TARGET WRITING RATE



JC-121C POSITION IDENTIFICATION (TOP VIEW)

B

TABLE I-10 (Cont.)

INSTRUMENT TRACKING INSTRUMENTS	DESIGNATION	LOCATION	SPECIAL PROVISIONS	COLLECTOR FOCAL LENGTH - f# (SERIAL #)	FIELD OF VIEW VERT. AND HORIZONTAL	NORMAL SAMPLING RATE	FILM TYPES	SPECTRAL RANGE	SPECTRAL RESOLUTION
35mm HIGH RESOLUTION CAMERA		G-1 SLAVE GIMBAL #1 FORWARD POSITION IN CANOPY	NONE	AERL/JONES 79.4" - f/14	0.5° x 0.7°	100 FR./SEC.	XT - PAN 35MM x 400'	.39 - 65	N. A.
MILLIKEN DBM V CAMERA	DBM #1	T-1 FORWARD MANUAL PEDESTAL AT OPEN DOOR	NONE	CANON 2" - f/1.2 (#43504)	8.4° x 11.7°	128 FR./SEC.	2475 REC. 16MM x 400'	.39 - .7μ	N A.
MILLIKEN DBM V (IR IMAGE CONVERTER CAMERA)	DBM #2	T-2 AFT MANUAL PEDESTAL AT OPEN DOOR	VARO I.C. TUBE .75 MAGNIF.; RELAY LENS: .47 MGNIF. IR INTERF AVCO #G-1 FILTER	CANON 4" - f/2 (#13769)	4.2° x 5.8°	64 FR./SEC.	2475 REC. 16MM x 400'	7 - 1. μ	01 - 4 μ AS FILTERED
MILLIKEN DBM V CAMERA	DBM #3	T-2 AFT MANUAL PEDESTAL AT OPEN DOOR	NONE	CANON 2" - f/1.2 (#45668)	8.4° x 11.7°	200 FR./SEC.	2475 REC. 16MM x 400'	.39 - .7 μ	N.A.
GSAP CAMERA	GSAP #1	G-1 SLAVE GIMBAL #1 FORWARD POSITION IN CANOPY	NONE	CANON 4" - f/2 (#15191)	4.2° x 5.8°	32 FR./SEC.	2475 REC. 16MM x 50'	.39 - 7	N.A.
GSAP CAMERA	GSAP #2	G-2 MASTER GIMBAL AFT POSITION IN CANOPY	NONE	CANON 2" - f/0.95 (#22120)	8.4° x 11.7°	32 FR./SEC.	2475 REC. 16MM x 50'	.39 - 7	N A
GSAP CAMERA	GSAP #3	T-1 FORWARD MANUAL PEDESTAL AT OPEN DOOR	FILTER: IR INTERF. AVCO #23	CANON 4" - f/2 (#10191)	4.2° x 5.8°	16 FR./SEC.	HSIR 13MM x 100'	.70 - .87μ	N.A.
GSAP CAMERA	GSAP #4	P6-3 SLAVE GIMBAL #2 AT OPEN DOOR	NONE	CANON 4" - f/2.0 (#15557)	4.2° x 5.8°	32 FR./SEC.	2475 REC 16MM x 50'	.39 - 7	N.A.
GSAP CAMERA	GSAP #5	T-2 AFT MANUAL PEDESTAL AT OPEN DOOR	OPTIONAL USE OF AIR WEDGE FOR MULTIPLE ATTENUATED IMAGES.	OMNITAR 12" - f/3.5 (#9706)	1.4° x 2°	32 FR./SEC.	2475 16MM x 100'	.39 - .7 μ	N.A.
GSAP CAMERA (U. V. MAKSUTOV IMAGE CONVERTER CAMERA)	GSAP #6	T-2 AFT MANUAL PEDESTAL AT OPEN DOOR	RCA #7404 I. T. TUBE MODIFIED S-21 PHOTO-CATHODE P-20 PHOSPHOR	MAKSUTOV 4" - f/1.1	6.5° x 8.9°	16 FR./SEC.	2475 16MM x 100'	35 - .40 μ	N.A.
CINE SPECTROGRAPH (QUEMO)	QUEMO	P6-3 SLAVE GIMBAL #2 AT OPEN DOOR	30ℓ/MM GRATING QUARTZ 4000 Å BLAZE HEATER BLANKET FOR LENS	QUESTAR (MODIFIED) 50.5" - f/14	0.8° x 1.1°	20 FR./SEC.	2475 REC. 35MM x 100'	.39 - 7	5A
U. V. LONG EXPOSURE SPECTROGRAPH	U.V. LEX	T-1 FORWARD MANUAL PEDESTAL AT OPEN DOOR	GRATING: 300 LINES/MM 3600 Å BLAZE	HILGER & WATTS 8" - f/3.5	10.2° x 6.9°	10 FR./SEC.	2475 35MM x 100'	.3 - .7μ	10A WHEN GRATING IS USED. OTHERWISE N.A.
IMAGE INTENSIFIER CINE SPECTROGRAPH	I^2	T-1 FORWARD MANUAL TRACKING PEDESTAL AT OPEN DOOR	75ℓ/MM AND ACHROMATIC WEDGE TO PLACE ZERO ORDER IMAGE IN FIELD OF VIEW S-20 CATHODE SURFACE P-11 PHOSPHOR	CELESTRON 40" - f/8	2°	40 FR./SEC.	TRI-X 35MM x 100'	.38 - .75	15A
BARNES 21-122C RADIOMETER/TRACKER		G-3 MASTER GIMBAL AFT POSITION IN CANOPY	DETECTORS S-20 PHOTOMULTIPLIER COOLED PbS	20" WIDE FIELD 80" NARROW FIELD	2° WIDE FIELD 1/2° NARROW FIELD	2550 CPS	RECORDED ON TAPE	.37 - .59 (PM) 1.75 - 2.75 (PbS)	N.A.

A

TABLE I-10 (Cont.)

...MAL ...PLING ...ATE	FILM TYPES	SPECTRAL RANGE	SPECTRAL RESOLUTION	MINIMUM DETECTABLE IRRADIANCE	SPATIAL RESOLUTION	DYNAMIC RANGE	TYPE OF DATA	DATA APPLICATION	REMARKS
...0 FR./SEC	XT - PAN 35MM x 400'	.39 - 65	N.A.	N.A.	.01 M.R.	N.A.	SPATIAL RESOLUTION OF VEHICLE AND WAKE	BODY HEATING, SHAPE AND DYNAMICS. WAKE DETAILS	HIGH SPECTRAL RESOLUTION FRAMING TELESCOPE
...R./SEC.	2475 REC. 16MM x 400'	.39 - .7 μ	N.A.	10^{12} WATTS/CM^2	1 M.R.	10^4	LUMINOUS INTENSITY; TIME; RELATIVE DEPLOYMENT	VISIBLE INTENSITY HISTORY; SCINTILLATION HISTORY; WAKE CHARACTERISTICS; RELATIVE SLOWDOWN	BASIC CINE TRACKING AND BORESIGHT CAPABILITY.
.../SEC.	2475 REC. 15MM x 400'	7 - 1. μ	.01 - 4 μ AS FILTERED	3×10^{-11} WATTS/CM^2	1 M.R.	10^4	INTENSITY VERSUS TIME IN THE NEAR IR	MULTI-TARGET NEAR I.R. INTENSITY HISTORY; SCINTILLATION HISTORY	EXTENDS MILLIKEN COVERAGE TO 1.1μ; IMAGING RADIOMETER.
...R./SEC.	2475 REC. 16MM x 400'	.39 - .7 μ	N.A.	4×10^{-13} WATTS/CM^2	1 M.R.	10^4	LUMINOUS INTENSITY; TIME; RELATIVE DEPLOYMENT	VISIBLE INTENSITY HISTORY; SCINTILLATION HISTORY; WAKE CHARACTERISTICS; RELATIVE SLOWDOWN	BASIC CINE TRACKING AND BORESIGHT CAPABILITY.
.../SEC	2475 REC. 16MM x 50'	.39 - 7	N.A.	1×10^{-12} WATTS/CM^2	1 M.R.	10^4	INTENSITY VERSUS TIME: POINTING POSITION AND TRACKING INFORMATION	INTENSITY HISTORY; POINTING EVALUATION FOR SLAVE GIMBAL #1; OBJECT IDENTIFICATION FOR THE HIGH RESOLUTION CAMERA	BORESIGHT RECORD FOR SLAVE GIMBAL #1 AND 35MM HIGH RESOLUTION CAMERA
.../SEC.	2475 REC. 16MM x 50'	.39 - 7	N.A.	1×10^{-12} WATTS/CM^2	1 M.R.	10^4	INTENSITY VERSUS TIME: POINTING POSITION AND TRACKING INFORMATION	INTENSITY HISTORY; POINTING EVALUATION FOR MASTER GIMBAL, OBJECT IDENTIFICATION FOR BARNES TRACKER	BORESIGHT RECORD FOR BARNES 122-21C RADIOMETER DATA AND POINTING PERFORMANCE ANALYSIS
.../SEC.	HSIR 16MM x 100'	.70 - .87 μ	N.A.	10^{-13} WATTS/CM^2	1 M.R.	10^4	NEAR I.R. INTENSITY, TIME; RELATIVE DEPLOYMENT	NEAR I.R. INTENSITY HISTORY; SCINTILLATION HISTORY; WAKE CHARACTERISTICS; RELATIVE SLOWDOWN	PROVIDES INTEGRATED I.R. DATA BY MEANS OF CINE INSTRUMENTATION.
.../SEC.	2475 REC 16MM x 50'	.39 - 7	N.A.	2×10^{-12} WATTS/CM^2	1 M.R.	10^4	INTENSITY VERSUS TIME: POINTING POSITION AND TRACKING INFORMATION	INTENSITY HISTORY; POINTING EVALUATION FOR SLAVE GIMBAL #2; OBJECT IDENTIFICATION FOR MARK IIA, MARK IIB AND QUEMO CINE SPECTROGRAPH	BORESIGHT RECORD FOR QUEMO CINESPECTROGRAPH, MARK IIA AND MARK IIB RADIOMETERS
.../SEC.	2475 16MM x 100'	.39 - .7 μ	N.A.	3×10^{-13} WATTS/CM^2	0.1 M.R.	10^4	LUMINOUS INTENSITY; TIME	WAKE CHARACTERISTICS; SCINTILLATION HISTORY; VISIBLE INTENSITY HISTORY	GREATER RESOLUTION.
.../SEC.	2475 16MM x 100'	.35 - .40 μ	N.A.	2×10^{-12} WATTS/CM^2 (AT 30 MSEC EXPOSURE)	1 M.R.	10^4	U.V. INTENSITY; TIME	U.V. INTENSITY HISTORY; WAKE CHARACTERISTICS IN U.V. REGION	EXTENDS GSAP COVERAGE TO THE U.V.
.../SEC.	2475 REC. 35MM x 100'	.39 - 7	5A	N.A.	0.02 M.R.	N.A.	SPATIALLY RESOLVED SPECTRA OF WAKE AND BODY	SPECTRAL CHARACTERISTICS OF WAKE	CAN BE USED AS A CINE TELESCOPE WITH GRATING REMOVED
.../SEC	2475 35MM x 100'	.3 - .7 μ	10A WHEN GRATING IS USED. OTHERWISE N.A.	2×10^{-11} W/CM^2-μ AT BLAZE (AT 25 MSEC EXPOSURE)	1 M.R.	10^4	U.V. AND VISIBLE INTENSITY; TIME; TARGET SPECTRUM	LOW-INTENSITY HISTORY IN U.V. AND VISIBLE; TIME-RESOLVED SPECTRA	HIGH-SENSITIVITY CINE CAMERA IN U.V. AND VISIBLE; OR U.V. AND VISIBLE CINE SPECTROGRAPH.
.../SEC.	TRI-X 35MM - 100'	.38 - .75	15A	WITH GRATING 2×10^{-14} WATTS/CM^2 μ at .555μ WITHOUT GRATING 1×10^{-17} WATTS/CM^2	.07 M.R.	10^3	SPECTRUM ON VEHICLE AND WAKE FROM LOW INTENSITY TARGETS	SPECIE IDENTIFICATION FOR VEHICLE AND WAKE	EXTREMELY HIGH SENSITIVITY SPECTROMETER. CAN BE USED AS A CINE TELESCOPE BY REMOVING GRATING
...PS	RECORDED ON TAPE	.37 - .59 (PM) 1.75 - 2.75 (PbS)	N.A.	1.2×10^{-16} WATTS/CM^2 7.4×10^{-14} WATTS/CM^2	N.A.	10^7 10^6	2-COLOR INTENSITY VERSUS TIME HISTORY	VEHICLE TEMPERATURE FROM 2-COLOR MEASUREMENTS	PROVIDES TRACKING INFORMATION FOR GIMBAL SYSTEM POINTING

AT 5 MILLISEC EXPOSURE

B

TABLE I-11

TRAP-TRANSPORTABLE INSTRUMENT TABLE AS OF 30 JUNE 1967
AVCO EVERETT RESEARCH LABORATORY

INSTRUMENT	DESIGNATION	LOCATION	SPECIAL PROVISIONS	COLLECTOR FOCAL LENGTH - f/	FIELD OF VIEW VERT AND HORIZONTAL	NORMAL SAMPLING RATE	FILM TYPES	SPECTRAL RANGE
FIXED INSTRUMENTS								
BALLISTIC CAMERA	BAL. #1 FID. #21	CAN BE MOUNTED ON ANY STEADY PLATFORM	BINARY CODED CHOPPING	6" - f/6.3	67° x 80°	1-4 CHOPS/SEC. PULSE WIDTH CODED	RXP 8" x 10" SHEET	.39-.65μ
BALLISTIC CAMERA (SPECTRAL OPTION)	BAL #2 FID. #11	CAN BE MOUNTED ON ANY STEADY PLATFORM	GRATING OPTIONAL 300 LINES/MM 6000A BLAZE	6" - f/6.3	67° x 80°	1-4 CHOPS/SEC PULSE WIDTH CODED; OR OPEN DURING ENTIRE RE-ENTRY	RXP 8" x 10" SHEET	.39-.65μ
SPECTRAL BALLISTIC CAMERA	SPECTRAL BAL 3 FID. #25	CAN BE MOUNTED ON ANY STEADY PLATFORM	GRATING 300 LINES/MM 6000A BLAZE	6" - f/6.3	67° x 80°	SHUTTER OPEN DURING ENTIRE RE-ENTRY	RXP 8" x 10" SHEET	.39-.65μ
METEOR SPECTROGRAPH	K-24 #1 FID. #14	CAN BE MOUNTED ON ANY STEADY PLATFORM	GRATING 300 LINES/MM 6000A BLAZE	7" - f/2.5	39° x 39°	2 SECS/FRAME	2475 REC. 5 1/2" x 56' ROLL	.39-.7μ
METEOR SPECTROGRAPH	K-24 #2 FID. #13½	CAN BE MOUNTED ON ANY STEADY PLATFORM	GRATING: 300 LINES/MM 6000A BLAZE	7" - f/2.5	39° x 39°	2 SECS/FRAME	2475 REC 5½" X 56' ROLL	.39-.7μ
TRACKING INSTRUMENTS								
MILLIKEN DBM V CAMERA	DBM V	MANUAL TRACKING TRIPOD PEDESTAL	NONE	CANON 2" - f/1.7	8.4° x 11.2°	128 FPS	2475 REC. 16MM x 400'	.39-.7μ
GSAP CAMERA *	GSAP	MANUAL TRACKING TRIPOD PEDESTAL	NONE	ANGENIEUX 1" - f/0.95	16.8° x 23.4°	16 FPS	2475 REC. 16MM x 100'	.39-.7μ
CINE TELESCOPE*		MANUAL TRACKING TRIPOD PEDESTAL	SPECIAL LENS MODIFICATION	QUESTAR (MODIF) 52.5" f/15	.8° x 1.1°	40 FPS	2475 REC 35MM x 100'	.39-.7μ

INSTRUMENT	SPECTRAL RESOLUTION	MINIMUM DETECTABLE IRRADIANCE		SPATIAL RESOLUTION	DYNAMIC RANGE	TYPE OF DATA	DATA APPLICATION	REMARKS
FIXED INSTRUMENTS								
BALLISTIC CAMERA	N.A.	6×10^{-13} watts/cm^2	10 MM/SEC TARGET WRITING RATE	1 M.R.	10^6	POSITION OF OBJECTS, TIME, LUMINOUS INTENSITY	TRAJECTORIES; OBJECT IDENTIFICATION, INTENSITY PROFILE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE
BALLISTIC CAMERA (SPECTRAL OPTION)	13A WHEN USED WITH GRATING	6×10^{-13} watts/cm^2 without grating 5×10^{-10} watts/cm^2-μ at blaze		1 M.R.	10^6	CAN BE USED FOR TYPES OF DATA LISTED ABOVE & BELOW; OR CONTINUOUS LUMINOUS INTENSITY COVERAGE OF ALL OBJECTS	OBJECT AND EVENT IDENTIFICATION, INTENSITY PROFILE, OR SPECIE IDENTIFICATION, TEMPERATURE	PROVIDES USEFUL QUALITATIVE RECORD OF RE-ENTRY
SPECTRAL BALLISTIC CAMERA	10A	5×10^{-10} watts/cm^2-μ		1 M.R.	10^6	SPECTRUM INTEGRATED OVER TARGET AND TRAIL.	SPECIE IDENTIFICATION, TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE
METEOR SPECTROGRAPH #1	8A	4×10^{-11} watts/cm^2-μ		1 M.R.	10^5	SPECTRUM INTEGRATED OVER TARGET AND TRAIL.	SPECIE IDENTIFICATION; TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE
METEOR SPECTROGRAPH #2	8A	4×10^{-11} watts/cm^2-μ		1 M.R.	10^5	SPECTRUM INTEGRATED OVER TARGET AND TRAIL.	SPECIE IDENTIFICATION, TEMPERATURE	SENSITIVITY DEPENDS ON TARGET ANGULAR RATE
TRACKING INSTRUMENTS								
MILLIKEN DBM V CAMERA	N.A.	1×10^{-12} watts/cm^2	5 MILLISEC EXP.	1 M.R.	10^4	LUMINOUS INTENSITY, TIME; RELATIVE DEPLOYMENT	VISIBLE INTENSITY HISTORY; SCINTILLATION HISTORY; WAKE CHARACTERISTICS, RELATIVE SLOWDOWN	BASIC CINE TRACKING CAPABILITY
GSAP CAMERA *	N.A.	2×10^{-12} watts/cm^2		1 M.R.	10^4	LUMINOUS INTENSITY, TIME, RELATIVE DEPLOYMENT	VISIBLE INTENSITY HISTORY; SCINTILLATION HISTORY; WAKE CHARACTERISTICS, RELATIVE SLOWDOWN	BASIC CINE TRACKING CAPABILITY
CINE TELESCOPE *	N.A.	N.A.		.02 M.R.	N.A.	DETAILED RESOLUTION	WAKE DETAILS	HIGH RESOLUTION FRAMING TELESCOPE

* THE CINE TELESCOPE AND THE GSAP CAMERA ALTERNATE ON THE TRACKING PEDESTAL.

NOTE: IN GENERAL, INSTRUMENTS ARE SUBJECT TO CHANGE BY MODIFICATION OR REPLACEMENT. LENSES, LENS SETTINGS, FILTERS, FILM TYPES, ETC. ARE ESPECIALLY SUBJECT TO CHANGE DEPENDING ON THE REQUIREMENTS OF THE PARTICULAR TEST TO BE MONITORED. REFER TO DATA SUMMARIES PUBLISHED IN THE RE-ENTRY DATA REPORTS FOR ACTUAL INSTRUMENTATION FOR EACH TEST.

TASK 6.0 OPERATIONS AND MEASUREMENTS

M. R. Twombly

Introduction

During this reporting period, the TRAP-1 and TRAP-6 aircraft (KC-135 and JC-121 respectively) and TRAP-Transportable ground station participated in twenty-four (24) re-entry monitoring missions on the Air Force Eastern and Western Test Ranges and the White Sands Missile Range, the majority of missions being accomplished at the latter location. It should be noted that a mission, as used herein, is an activity for which a monitoring platform is on station and the missile for which measurements are planned is launched. Therefore successful and unsuccessful missile flights are included; last minute test postponements, even though platforms were on station in the re-entry area, are not. A summary of activities for this period is presented in Table I-12 which, for purposes of completeness, also includes aircraft movement and maintenance information. The location, referred to in parenthesis after each mission insertion, indicates the staging area of the aircraft or the monitoring location of the ground station, as applicable.

Summary of Field Activities

The TRAP-1 aircraft, after monitoring two extremely important Air Force missions on the Eastern and Western Test Ranges, returned to Dayton in late January where all instrumentation was removed in preparation for its input to Martin Marietta Co., Baltimore, in February, for a modification adding eleven optical windows. On completion of the modification, an aircraft IRAN (Inspect and Repair as Necessary) is scheduled and, at this writing, it will become available again for equipment reinstallation during the month of September. The effort associated with, and a description of the equipments to be installed after modification are detailed in task 8.0 of this report.

TABLE I-12
OPERATIONS AND MEASUREMENTS ACTIVITY SUMMARY

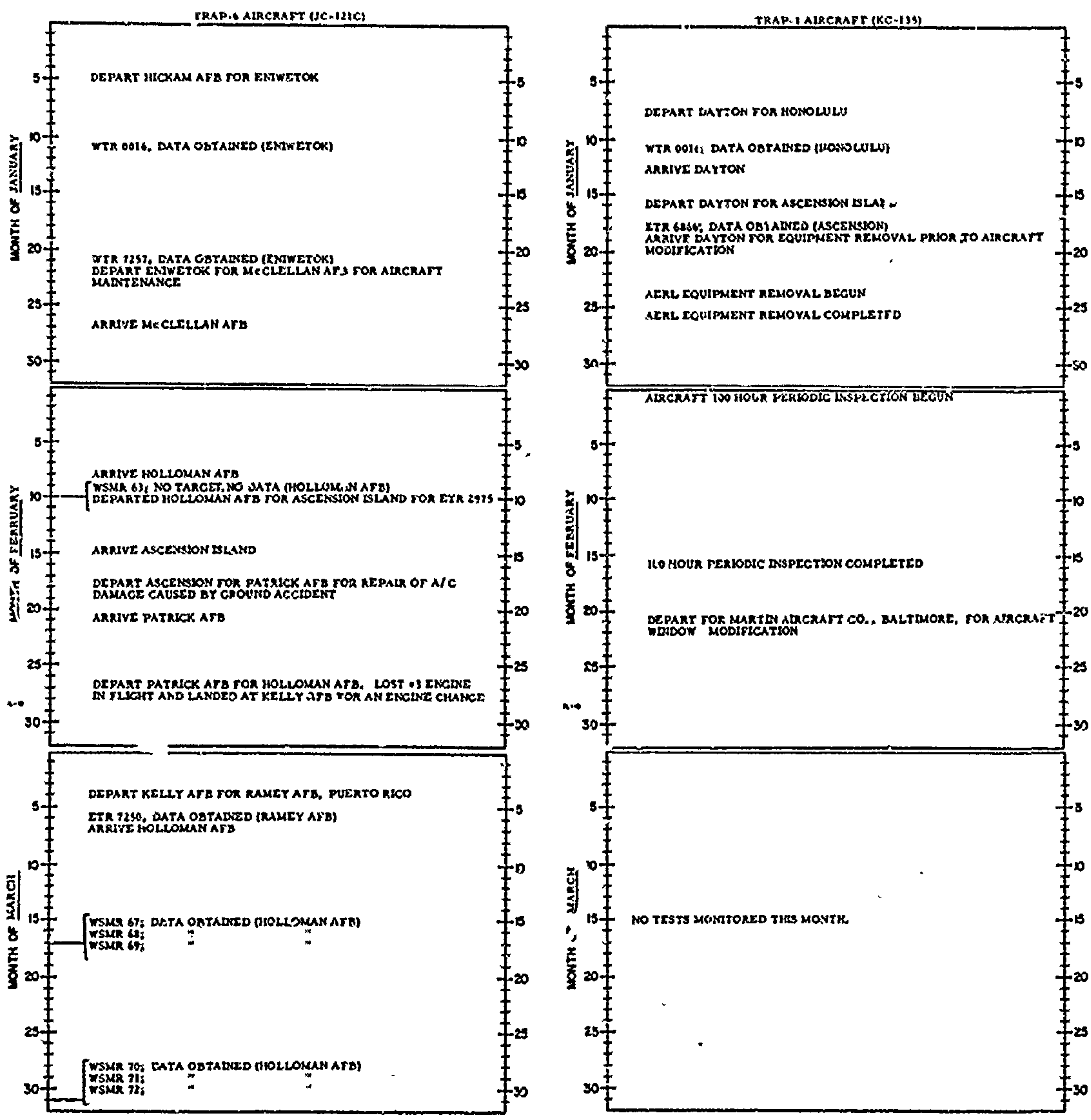
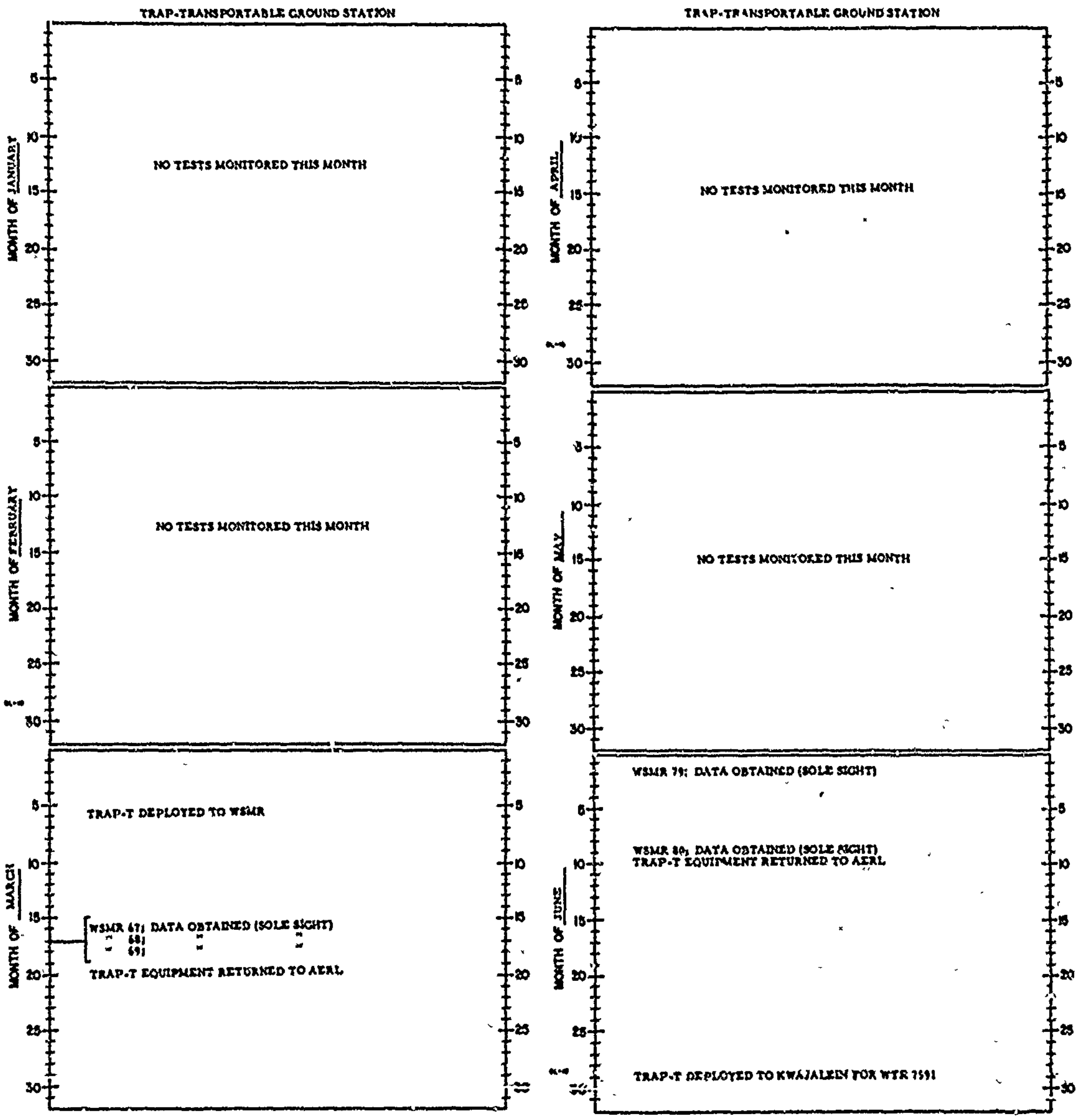


TABLE I-12 (CONT'D)

MONTH	TRAP-6 AIRCRAFT ([illegible]-121 [illegible])	TRAP-1 AIRCRAFT (KC-135)
MONTH OF APRIL	WSMR 73; NO TARGET, NO DATA. AIRCRAFT IN CLOUDS DURING RE-ENTRY (HOLLOMAN AFB) WSMR 74, " " WSMR 75; DATA OBTAINED (HOLLOMAN AFB) DEPART FOR McCLELLAN AFB FOR AIRCRAFT REPAIRS	NO TESTS MONITORED THIS MONTH.
MONTH OF MAY	ARRIVE HOLLOMAN AFB DEPART HOLLOMAN AFB FOR ASCENSION ARRIVE ASCENSION DEPART ASCENSION FOR HOLLOMAN AFB; ETR 3572 SLIPPED UNTIL JUNE ARRIVE HOLLOMAN AFB	NO TESTS MONITORED THIS MONTH.
MONTH OF JUNE	WSMR 79; DATA OBTAINED (HOLLOMAN AFB) WSMR 80; DATA OBTAINED (HOLLOMAN AFB) DEPART FOR ENIWETOK ARRIVE ENIWETOK WTR 3060, DATA OBTAINED (ENIWETOK) WTR 8022; DATA OBTAINED (ENIWETOK)	NO TESTS MONITORED THIS MONTH.

TABLE I-12 (CONT'D)



Because of the unavailability of TRAP-1, the TRAP-6 aircraft was called upon to move frequently and expeditiously during the reporting period in order to support SAMSO designated missions on all three of the National Test Ranges. After supporting tests in the Kwajalein area during the month of January, the aircraft then monitored a mission in early February at WSMR, departing immediately thereafter for Ascension. When a ground accident caused structural damage to the aircraft which could not be repaired at that location, the aircraft departed for Patrick AFB for repairs after which, an uprange BOA ETR mission was covered in early March. The following two months saw the aircraft monitoring several missions at WSMR. Another trip was then made to Ascension in May; however, when the designated mission slipped several weeks, the aircraft returned to WSMR again to support missions there. In early June, when activities at the Western Test Range increased, the aircraft then returned to Eniwetok to provide the required TRAP support.

The TRAP-Transportable ground station continued to be a valuable adjunct to the TRAP-program during this period of activ'ty. The system was deployed to WSMR on two occasions during which the TRAP aircraft were engaged in providing support on other Ranges, and monitored five missions at that location. In late June, the system was deployed to Kwajalein to provide low altitude coverage on an extremely important mission scheduled in early July.

Operations Activities

Earlier this year, a Field Operations group was established and given the responsibility for the operational aspects of all AERL platforms (TRAP and NIKE-X), so as to provide a commonality of approach to field procedures across all programs. The training of all field personnel will also fall within the responsibilities of this group.

Due to serious inadequacies over the past several months in the TRAP-6 Base Support at Eniwetok, AERL representatives attended a meeting at SAMSO in January to discuss critical items such as crew housing, transportation aircraft ground support equipment and POL, etc. On the following day, the meeting was moved to Vandenberg AFB with AFWTR representatives also in attendance. All items were again discussed, and action items directed

to appropriate individuals. The Base Support situation at Eniwetok was reviewed in June, prior to the TRAP-6 arrival, and was found to be significantly improved.

A meeting was held at Holloman AFB in March to discuss the Base Support requirements of the TRAP-6 aircraft at that location over the next eighteen-month period. In attendance were representatives from the SAMSO Athena Field Office, AERL and Holloman AFB. The Base Support requirements listed in the TRAP-6 contract were reviewed, and it was determined that all items could be supplied with a few exceptions which were not available. These items have subsequently been requisitioned and are presently on site.

Training (G. Kaiser)

Training activities have been increased to upgrade the efficiencies of the data gathering personnel. A program has been established whereby new personnel are assigned to their experienced counterparts as part of a "total immersion" training technique, in which the experienced individual tutors his supernumerary in all pertinent phases of instrument and system characteristics. As part of this, during equipment installations or test periods when an aircraft is at a CONUS location, trainees are subjected to formal instruction in the procedures by their counterparts. Further instrument/system familiarity is gained by having personnel accompany instruments which are returned to vendor facilities for service or modification. Another similarly successful training technique is the establishment of training classes on new equipment in which a vendor supplies a competent engineer to conduct a series of instruction in the theory, operation and maintenance of subject equipment. All of the aforementioned have proved to be extremely successful in advancing the education of newly assigned personnel.

Also, a training course in semiconductor theory and applications has been instituted for TRAP field personnel who operate and maintain electronics equipments. This consists of a correspondence course augmented with class presentations by AERL engineers to expand the knowledge of field personnel with respect to semiconductor theory, devices and applications of these devices. The course is considered to be a thorough, easily understandable source of information which will aid trainees in the understanding and use of equipments containing the latest semiconductor devices.

Improved Training Aids

Evaluation of tests conducted both at AERL and in the field indicated the necessity of improving individual skills in the use of pyrometric measuring devices associated with photometric calibration. As a result, a training aid was designed and fabricated which consists of a variable, calibrated light source, with a pyrometer mounted on an adjustable rack. This new training unit allows field personnel to quickly develop focusing and scale reading skills, thereby increasing the accuracies of brightness temperature readings performed during field calibrations.

The efficiency of the training program is expected to be increased by the acquisition of audio/visual training aids. Plans are underway to videotape subject matter which will enable the training department to conduct more intensive instruction, especially in those areas which, by their nature, are complicated and necessarily repetitive. An example of the specific use of video tapes is illustrated by an existing pilot tape which introduces trainees to the intricacies of servicing a high speed cine camera. In addition to allowing a wide scope of readily available subject matter, the video tape medium will greatly reduce the demands on personnel now required to conduct courses, since the tape is adjunct to the training program will effect both an upgrading of individual technical skills as well as accelerate the entire training effort.

Tracker Training

Acquisition and tracking training at AERL is being conducted on a continuing basis with the goal of introducing the basic art of tracking to new trainees and maintaining the proficiency of experienced trackers. It is planned to upgrade the tracking simulator in the near future by the addition of gear driven position indicating output potentiometers on the tracking pedestal and a recording device which will allow tracking efforts to be accurately recorded on a time and position basis. The present method of recording trainee performance utilizes a polaroid camera mounted on the tracking pedestal, and while extremely useful in evaluating tracking accuracies, it does not allow a time-based analysis to be made. When this modification is completed, the tracking record will permit an analysis of every motion made by the tracker and an evaluation of those exact areas of mistrack as well as the time delay involved in target acquisition.

TASK 8.0 TRAP-1 UPGRADE

P. D. Howes

Introduction

The task of upgrading the TRAP-1 re-entry monitoring platform was initiated by CCN #1 to the AF 04(694)-865 contract which was received during this reporting period. What is presented in this section by way of an activity summary is the proposed design for the upgraded and interim operational systems for TRAP-1. The interim system is that complex of equipments which will be operational until procurement of the major system components for the upgraded system has been completed.

The pacing item in terms of schedule for completion of the upgraded TRAP-1 system is the gimbal subsystem. At this time, proposals from several vendors are under evaluation by AERL. These gimbals, further described in the following pages, will be 3-axis subsystems which will be capable of operating in azimuth, elevation, and fore and aft translation to allow the widest field of view possible from behind the aircraft windows.

The interim system is scheduled to become operational on approximately 1 October 1967. The final upgraded system operational date is not firm at this time but is expected to occur approximately one year later.

TRAP-1 Platform

The TRAP-1 platform is a specially modified USAF JKC-135A (S/N 55-3134) aircraft which is used as a re-entry monitoring platform to acquire optical re-entry radiation data in support of ABRES and BMRS experiments.

The TRAP-1 aircraft is currently undergoing modifications by the Government which will permit the implementation of an upgraded measurement system capable of meeting the present and future optical data needs of the TRAP program and its users. AERL has been providing close support to SAMSO and Aerospace in defining the modification requirements for the platform.

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Figure I-19 shows the JKC-135 platform before modification. During the modification, 11 optical quality windows are being installed in the left side of the fuselage. These windows will provide a clear viewing diameter of 27 inches and will permit the installation of a matrix of instruments which will markedly enhance the optical data acquisition capabilities of this platform. When completed, the outward appearance will be quite similar to the TRAP-7 aircraft shown in figure I-20.

Aircraft Configuration--A basic aircraft configuration and equipment layout for the TRAP-1 aircraft was conceived by AERL after considerable thought had been given to the optimum location for the various components in an effort to gain the maximum viewing area for monitoring purposes and, at the same time, not compromise the weight and balance of the aircraft or crew comfort.

The preliminary aircraft layout for the upgraded TRAP-1 system is shown in figure I-21. Basically, the area along the left side of the fuselage has been allocated as the location for all of the sensors and their mounts, while the right hand side has been allocated for the installation of all of the supporting systems, controls, and displays, power distribution, and on board support equipment.

TRAP-1 Canopy

AERL has participated with the Martin-Marietta Company in a conceptual design for a new canopy for TRAP-1. This canopy will be configured to provide a convertible window area. The convertible feature will ultimately allow use of the canopy in any of three modes:

a. Two 30" x 60" glass windows with a central 17" x 24" window.
b. Two sets of openable doors replacing the 30" x 60" windows to allow use of the canopy in an open cavity configuration.
c. Any combination of a. and b. above.

The primary advantage of the large window is that long, gimballed payloads are afforded a superior field of view with no wing cutoff, whereas payloads of this nature otherwise might require a 4-axis gimbal for the same or less angular coverage if mounted behind a fuselage-located circular window. Additionally, fixed instrumentation placed in the canopy will have

Fig. I-19 TRAP-1 aircraft before modification.

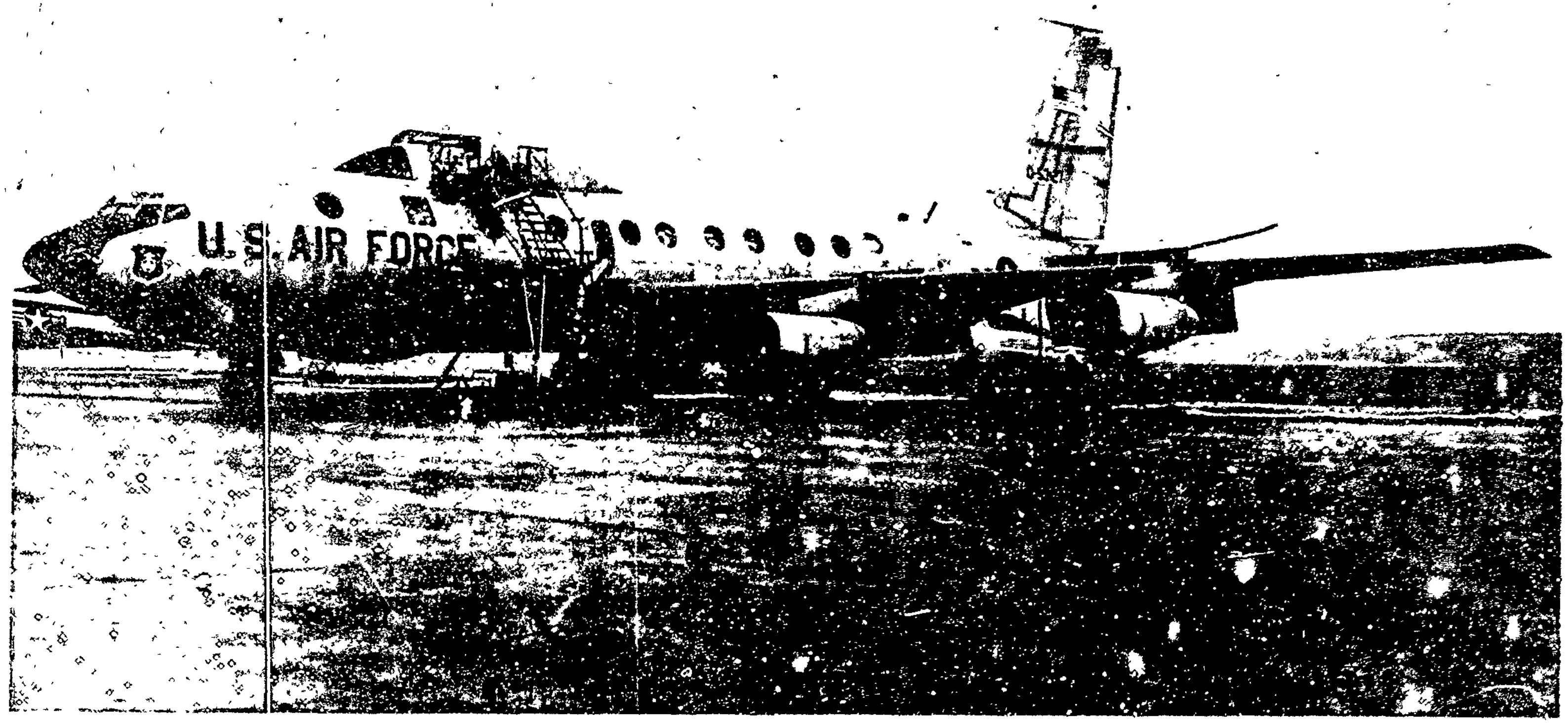

Fig. I-20 TRAP-7 aircraft after modification.

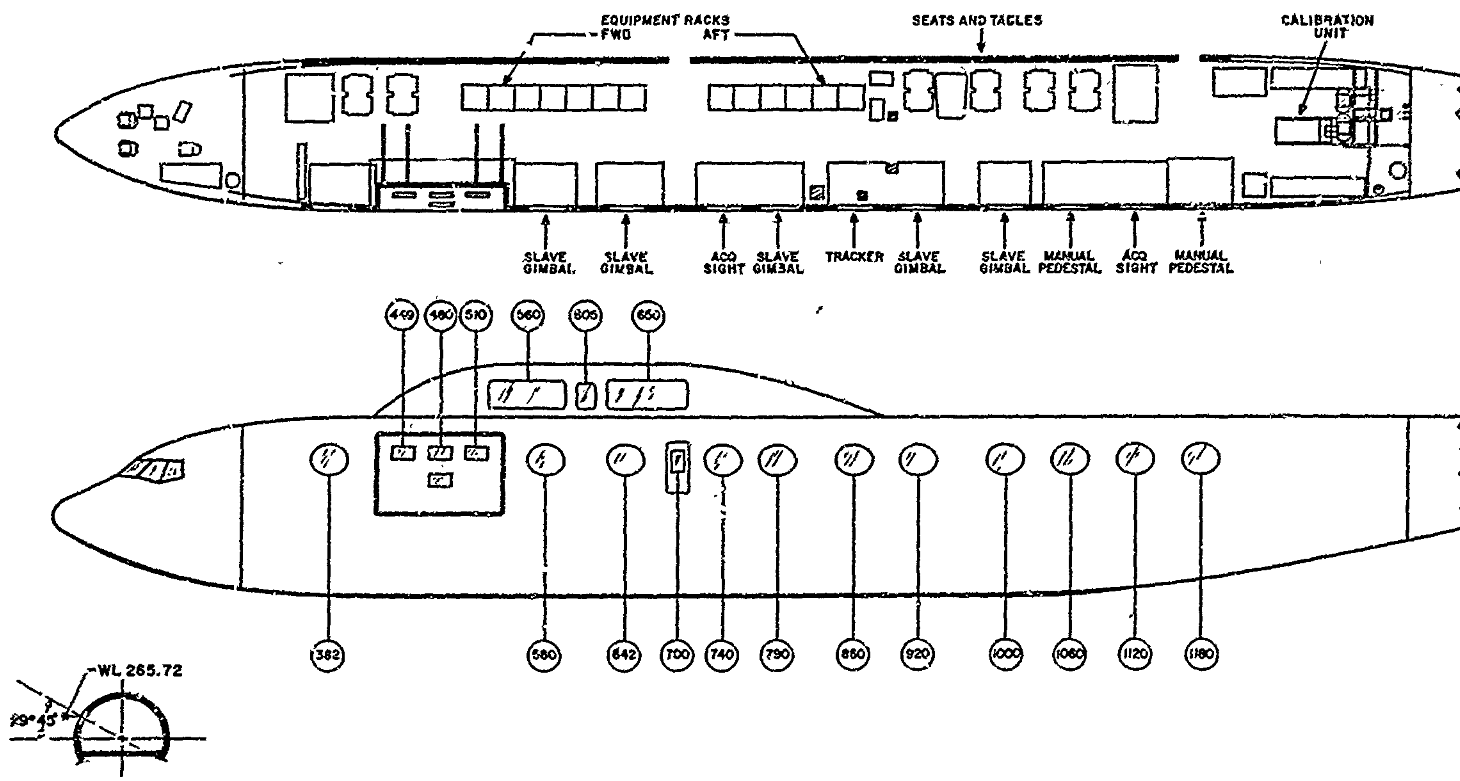

Fig. I-21 Upgraded TRAP-1 aircraft configuration layout.

less field of view obstruction than from any fuselage-mounted position, with the possible exception of the cargo door or window P1.

Utilization of the canopy in an open cavity configuration which provides the optimum location for future infrared sensors is the ultimate usage to which the canopy design is directed. The open cavity approach is necessary for mid- and long-wavelength infrared measurements, where optical window material is not obtainable. The canopy location for such instruments also places them well away from the engine exhaust area which creates severe optical signal degradation in the IR wavelength regions.

The scope necessary to realize and utilize the open cavity configuration is outside of the present upgrade task. The canopy will be utilized in the upgraded system with the glass windows installed and with the matrix as shown in figure I-22.

Upgraded System

In the upgraded TRAP-1 system, functional flexibility has been incorporated to minimize future perturbations caused by changes in the sensor matrix, to provide support data for the analytical efforts on both sensors and systems, to allow more rapid recall of recorded data for analysis, to insure a high quality and reliability of all data collected and, in addition, to include sufficient capability to facilitate sensor and systems testing prior to a mission to maximize the probability of success.

The upgraded system configuration for TRAP-1 is depicted in figure I-22. This concept and configuration and performance requirements have been evaluated during a preliminary design phase. The concept exhibits a flexible solution to the problems arising from requirements that are determined by a continually changing program. The system consists of the following major elements integrated into the JKC-135 aircraft:

a. Re-entry Measurement Sensors
b. Pointing System
c. Data Acquisition and Recording System
d. Timing and Sensor Control System

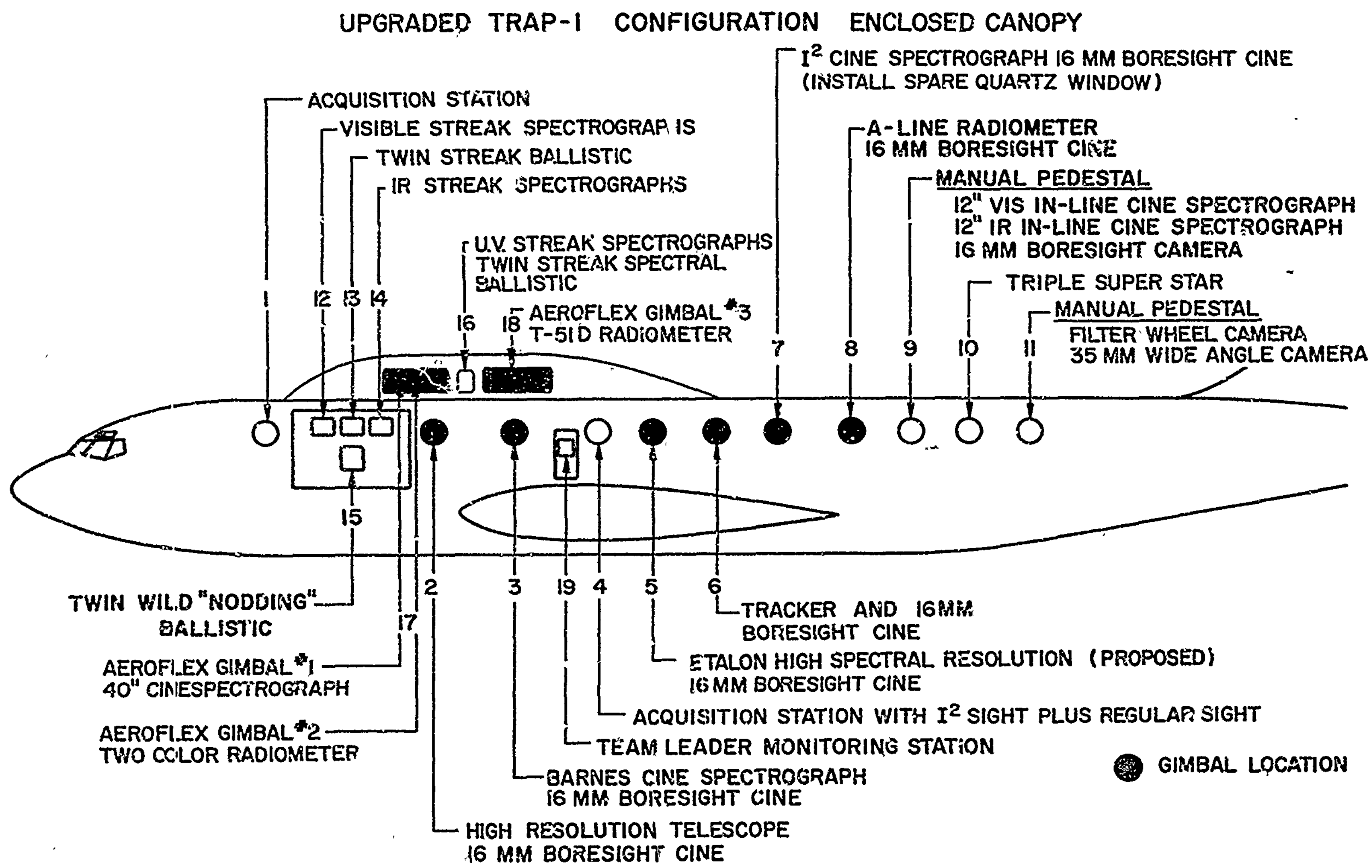

Fig. I-22 Upgraded TRAP-1 system configuration.

Measurements to be made by TRAP-1 must be self-contained and, consequently, a mixed instrumentation complex which meets or exceeds the program needs is required. These measurements will include metric, spectral, radiant intensity, and optically resolved data. The metric data, while closely related to all measurements, is uniquely oriented to measurement of trajectories and re-entry complex definition. Spectral data is required both to determine and to investigate vehicle performance, as is the radiant intensity data. The optically resolved data has major usefulness in determining and measuring precise performance or anomalies. This, then, is the framework within which the TRAP-1 instrument system, its sensors, support equipment, and subsystems have been defined and system design is being accomplished.

TRAP-1 Windows

The existing TRAP-1 window material consists of crown glass in eight of the eleven fuselage windows. Two of the remaining three windows are water-free quartz and one is fused silica. The cargo door windows are believed to be fused silica and will be tested for verification.

Fused silica is required for instruments with wavelength responses extending into the ultraviolet past approximately 0.38 μ, whereas water-free quartz is refined beyond approximately 1.7 μ and exhibits good transmission to approximately 3.0 μ.

Sensors

The sensor complex for the upgraded TRAP-1 system is configured to produce interpretable data for use in the evaluation of re-entry systems being tested by BSD and to serve as a basis for studies designed to obtain an understanding of the physical processes involved in re-entry. Specifications of the specific sensors to be employed are summarized in table I-13 or are included below as required for the discussion of a sensor upgrade activity. Sensor locations are shown in figure I-22. In this section, sensors are grouped by major function into four categories: metric, spectral, high resolution, and intensity.

TABLE I - 13

SENSOR CHARACTERISTICS

Twin Streak Ballistic Camera

Lens	6" focal length, f/6.3 metrogon
FOV	80° vertical x 114° horizontal
Film	8" x 10" sheet
Spectral range	3900 Å - 6500 Å
Minimum detectable irradiance	6×10^{-13} watts/cm^2
Spatial resolution	1 mr

Note: Also operable with a 4 chop/sec pulse width code as a mission option.

Twin Wild/AERL Nodding Ballistic Camera

Lens	Universal Aviogon, 6" focal length f/5.6
FOV	74° vertical x 74° horizontal (single camera)
Sampling rate	1 - 4 chops/sec, pulse width coded
Recording medium	9 1/2" x 10 1/2" glass plate
Spectral range	3900 Å - 7000 Å
Minimum detectable irradiance	5×10^{-13} watts/cm^2
Spatial resolution	0.1 mr

Twin Spectral Ballistic Camera

Lens	6" focal length, f/6.3 metrogon
FOV	80° vert x 114° horiz
Spectral range	3800 - 6500 Å
Spectral resolution	6 Å
Spatial resolution	1 mr

TABLE I - 13 (Cont'd)

Twin Spectral Ballistic Camera Contd.	
Minimum detectable irradiance	1 x 10^{-12} watts/cm^2
Grating:	
Lines per mm	300
Blaze wavelength	6000 Å
Barnes Cinespectrograph	
Grating:	
Lines per mm	400
Blaze wavelength	4000 Å
Central wavelength	5095 Å
Lens:	
Type	Barnes Maksutov corrected Newtonian
Focal length	12" (305 mm)
Aperture ratio	f/2.7
FOV	5.2° x 10.8°
Camera:	
Type	Photosonics 5C
Film size	70 mm
Sample rate	5, 10, 15 f/s
Shutter angle	Variable 30° - 120°
System:	
Spectral range	3000 - 7000 Å (to 9000 with different grating)
Spectral resolution	2 Å
Spatial resolution	7.8 m at 10^5 m
Dispersion	81.5 Å/m
Synthetic zero order	5090 Å

TABLE I - 13 (Cont'd)

40" Telespectrograph	
Manufacturer	General Electric
Visible Prism:	
Grating (B & L type 35-63-71-63)	
Lines per mm	200
Blaze wavelength	5500 Å
Center wavelength	5100 Å
Blaze region	3700 - 7300 Å
Prism:	
Material	BSC-2 glass
Angle	11° 32'
Infrared Prism:	
Grating (B & L type 35-53-70-63)	
Lines per mm	200
Blaze wavelength	7800 Å
Center wavelength	7100 Å
Blaze region	5200 - 11,000 Å
Prism:	
Material	BSC-2 glass
Angle	16° 4'
Telescope:	
Manufacturer	Wollensak
Focal length	40-inch
Effective f/no.	f/8.0
Type	Cassegrainian
Corrector	Maksutov
Primary	Spherical f/6.3
Camera:	
Manufacturer	Giannini Model 207
Format	Double frame 35 mm 36 x 24 mm

TABLE I - 13 (Cont'd)

40" Telespectrograph Contd.	
Camera Contd:	
Framing	Fixed 10.89 f/sec
Shutter angles	1, 7, 17 degrees
Exposure times	0.76, 5.3 and 13 msec
Film capacity	Special magazine, 100 ft
System:	
Spectral resolution	1 Å
Spatial resolution	2 mm at 10^5 m
FOV	$2^\circ \times 1.4^\circ$
Size	10 x 19 x 24 inches
Weight	80 lb (less balance weight)
Moment of inertia	3.2 $lb\text{-}ft\text{-}sec^2$
Sensitivity (tentative)	3×10^{-10} $(w/cm^2\text{-}\mu)$
Coverage:	
Visible prism	4300 Å - 6100 Å
Infrared prism	6200 Å - 8000 Å
Infrared In-Line Cinespectrograph	
Manufacturer	General Electric
Grating:	
Lines per mm	300
Blaze wavelength	6000 Å
Center wavelength	7615 Å
Prism:	
Material	BSC-2 glass
Angle	25° 5'
Lens:	
Type	Kodak Aero-Ektar
Focal length	12"
Aperture ratio	f/2.5
FOV	4°

TABLE I - 13 (Cont'd)

Infrared In-Line Cinespectrograph Contd.		
Camera:		
	Type	Traid 75A
	Film size	35 mm
	Sample rate	10, 20, 40, 60 f/sec
	Shutter angle	160°
	Exposure time (msec)	44.5, 22.2, 11.1, 7.4
System:		
	Spectral range	6360 - 8860 Å
	Spectral resolution	4 Å
	Spatial resolution	0.07 mr
	Dynamic range	10^2
	Sensitivity	9×10^{-6} w/cm^2-μ
Visible In-Line Cinespectrograph		
	Manufacturer	General Electric
Grating:		
	Lines per mm	300
	Blaze wavelength	5080 Å
	Center wavelength	4878 Å
Prism:		
	Material	BSC-2 glass
	Angle	15° 33'
Lens:		
	Type	Kodak Aero-Ektar
	Focal length	12"
	Aperture ratio	f/2.5
	FOV	4°

TABLE I - 13 (Cont'd)

Visible In-Line Cinespectrograph Contd.		
Camera:		
	Type	Traid 75A
	Film size	35 mm
	Sampling rate	10, 20, 40, 60 f/sec
	Shutter angle	160^{o}
	Exposure time	44.5, 22.2, 11.1, 7.4 msec
System:		
	Spectral range	3750 - 6050 Å
	Spectral resolution	4 Å
	Spatial resolution	0.07 mr
	Dynamic range	10^{2}
	Sensitivity	3×10^{-6} w/cm^{2}-μ
Atomic Line Radiometer		
	Manufacturer	GCA/AERL
Optics:		
	Aperture	7"
	Focal length	18.5"
	FOV	2^{o}
	Spatial filter	60 sector, 1800 rpm
	Birefringent filter	Comb spacing - 6 Å at 5900 Å
	Dielectric filter	5893 Å center wavelength, ~24 Å passband
	Outputs--signal	Two ~ 2.7 decade each basic frequency 1800 Hz sidebands 1650 and 1950 Hz sync pulse phase reference for polarizer
	Detector	S-20 photomultiplier, EMR type 541 E-01
	NEPD (tentative)	5×10^{-15} watts/cm^{2}
	Min. det. intensity	$\frac{2 \text{ watts}}{\text{ster}}$ at 111 km

TABLE I - 13 (Cont'd)

Atomic Line Radiometer Contd.	
Optics Contd.	
Modulation frequency	150 cps
Dynamic range	4.5 decades
Ambient temperature range	-65° to $+135^{\circ}$F
Controlled internal temp.	$75^{\circ} - 80^{\circ}$ F
Barnes Vis/IR Radiometer	
Aperture	8 in.
FOV	$1^{\circ} \times 1^{\circ}$ both channels, reducible to $1/2^{\circ}$ in both channels by field stop activated by a front panel switch
Detectors: Visible Channel	S-20 PM
NEFD (1 cps BW)	8×10^{-16} watts/cm^2 (tentative)
IR Channel	Thermoelectrically cooled PbS
NEFD (1 cps BW)	8×10^{-14} watts/cm^2 (tentative)
Spectral range (points of 1/2 max response):	
Visible	3700 - 5600 Å
IR	1.75 - 2.75 μ
Background suppression	300:1
Reticle chopping frequency	730 cps
Dynamic range	10^5 max
Output impedance	Less than 1000 ohms. Logarithmic output channels. Output 0 to + 10 VDC, linear $\pm$ 5 VAC, for each channel.
Sun shutter provided for protection against solar radiation:	
Size	~ 11" dia, 20" length
Weight (of telescope)	~ 35 lbs.

TABLE I - 13 (Cont'd)

80" Jones High Resolution 35 mm Camera

Camera:

Type	Mitchell 35 mm GC
Format	18 x 24 mm (single frame)
Framing rate	0 - 128 fps, continuously variable by means of an external variac
Shutter angle	0 - 170° variable in 15° increments
Film load	35 mm x 400' magazine
Running time	50 sec at 128 fps
Weight	40 lb with film
Boresight provision	A viewfinder is attached to the door on the side of the camera. A rack-over device provides a means of sliding the camera to the side to that the viewfinder looks through the lens.
Timing lights	Neon type
Exposure	When the variable shutter is set to 15°, which is the first opening above zero, the exposure time at 128 fps is 0.325 msec. A modification could provide an exposure as small as 22 μ sec, without reducing the light cone of the optical system.

Optical System:

Focal length	80"
Aperture	6.25" O.D. x 2.3" I. D., resulting in an effective dia. of 5.7" or f/14.
FOV	.5° vertical, 7° horizontal on the 18 x 24 mm format
Resolution (XT Pan Film)	1.5 to 2 sec of arc
Rayleigh limit	1.0 sec

Metric Sensors

Three types of metric sensors will be installed on TRAP-1 to insure comprehensive trajectory determination. The three types, Twin Streak Ballistics, Wild Ballistics, and Super Stars, have been employed successfully on TRAP platforms for several years. Reduction methods have been well documented.

Twin Streak Ballistic

A Twin Nodding Ballistic will be used as a streak ballistic. In this mode, the camera is normally operated unchopped and in a fixed position and provides a valuable total event record of the entire re-entry. This record, uninterrupted by chopping, is extremely useful for object identification and scintillation history and provides a necessary data reduction aid by providing a continuous record of re-entry data. Also, this camera will have the capability of being utilized in a nodding configuration, depending on mission objectives. While the Nodding Twin Ballistics and Nodding Wild Ballistics, with their stretched out star traces, are generally the best for reduction, the nodding does dim the star traces to some extent. Should poor observation conditions prevent the ready identification of star traces, such identification is made by utilizing the streak ballistics.

The flexibility afforded by employing a set of standard ballistic cameras in a streak mode is of major operational importance. It allows the option of using the streak ballistic as a standard Twin Nodding Ballistic for multiple object re-entries whenever it is desirable to time phase the ballistic data to preclude severe overtracing of objects. In addition, the different location of the streak ballistic allows it to be used as a standard twin ballistic if OSP changes cause wing cutoff of the re-entry phenomenon.

Wild/AERL Nodding Ballistic

A Twin Wild/AERL Nodding Ballistic camera will be utilized to acquire high spatial resolution ballistic data for all objects in the re-entry complex. The Wild camera has been of great value in identifying closely spaced objects and in obtaining deployment data and has been installed on all of the AERL TRAP aircraft for some time.

Super Star

A Twin or Triple Super Star camera will be utilized to provide increased sensitivity over the Wild and AERL ballistic cameras. The gain in sensitivity allows recording of higher altitude images or faint objects which are below the thresholds of the other ballistics. Such an instrument has successfully been used to record decoy position data in lower altitude regions.

Although the field of view of the Super Star camera is small in comparison to the standard ballistics, star images are sufficiently recorded for use in nighttime re-entry trajectory analysis. These "Super Stars" will be aligned in parallel with the flight path and have slightly overlapping fields of view to monitor a substantial portion of a re-entry.

An additional advantage of the Super Star cameras is that they are a framed rather than a single frame instrument. The framing prevents obscuration of images sometimes caused on a regular ballistic by the close proximity in a direction normal to the flight path or, for instance, a faint R/V image and an overexposed rocket body image. If any time lag exists along the flight path between objects, the angular separation is immediately evident and relative angular position information between objects at any instant is readily determinable in both a qualitative and a quantitative sense provided the objects fall within the field of view. Superimposing all frames of data via alignment of fiducial marks on the film will comprise the total portion of the re-entry covered and readily indicates images writing on the same area of the film at later times.

In essence, the primary reason for "Super Star" cameras is to obtain data on faint objects or high altitude optical data, which is primarily utilized to add to both the accuracy and amount of trajectory data available from other ballistic camera reduction.

Characteristics of the existing Super Star presently employed on the TRAP-6 aircraft are compared in table I- 14 to one of the choices being considered for the upgraded instrument planned for TRAP-1.

TABLE I-14

SUPER STAR CHARACTERISTICS

	Existing AERO-EKTAR	Proposed ASTRO BERLIN
LENS:		
Focal Length	305 mm	150 mm
Diameter	122 mm	100 mm
Figure of Merit*	48.8	66.6
Resolution		
Spatial	25 l/mm	25 l/mm
Angular	1.3×10^{-4} radians	2.7×10^{-4} radians
CAMERA:	K-24	MAUER 70 mm
Format	140 mm^2	57 mm^2
Field-of-view	$26^\circ \times 26^\circ$	$22^\circ \times 22^\circ$
Twin System	$26^\circ \times 48^\circ$	$22^\circ \times 40^\circ$
Frame Rate	2 frame/sec maximum	6 frame/sec maximum
	1 frame/sec normal	1 frame/sec normal
Frame Time	< 0.5 sec	~ .2 sec

*Figure of Merit for a Streak Camera = $(\text{diameter})^2/\text{focal length}$

Spectral Sensors

Spectral data on re-entry objects is obtained by both fixed and tracking sensors. Both types of sensors are utilized to permit the gathering of data on both a single object of interest as well as on all objects in the re-entry complex. The fixed sensors to be utilized on the TRAP-1 aircraft will be framing streak spectrographs and a twin spectral ballistic camera.

Streak Spectrographs

Framing streak spectrographs are superior to cinespectrographs for the purpose of detecting isolated, moderately weak spectral lines and bands in the presence of a continuum.

The reason for the difference is as follows. On a well tracked cinespectrograph record, in order to be detected reliably (either by eye, on an anamorphically widened print, or on a microdensitometer tracing), based on our experience, a line must have a peak density at least ~ 0.3 D above the background continuum. Lines weaker than this will not be distinguishable from random emulsion grain. However, on a streak spectrogram, lines having a peak density of ~ 0.1 D above the continuum can be detected readily by eye because the eye automatically performs an integration along the time axis of the spectrogram, thereby improving the effective signal-to-noise ratio. Similar statements apply to the molecular bands. The validity of this argument is easily demonstrated by masking all but a narrow strip of a streak spectrograph record to simulate a cinespectrogram. It will be found that weak features will not be seen which are readily identified when the entire streak spectrograph record is exposed to view.

The existing class of streak spectrographs currently in use by AERL will be upgraded for the TRAP-1 platform. Primary requirements for the upgraded instruments are:

a. Field of view in excess of 30°.

b. High sensitivity.

c. High angular resolution.

Desirable features include minimum cycle time between successive frames and small physical size.

To provide optimum and complete spectral coverage of the re-entry complex from .35 μ to .9 μ requires three separate instruments, one for each portion of film recordable spectrum:

Ultraviolet	-	.35 μ - .55 μ
Visible	-	.4 μ - .7 μ
Infrared	-	.6 μ - .9 μ

With a minimum field-of-view requirement of 30°, the largest film format practical is desired to allow use of the longest possible focal length to maximize angular resolution. The specific lens requirements for each wavelength interval are described below.

Ultraviolet System

Three possible instruments have been considered to meet the desired design requirements of high UV sensitivity and wide field of view with as high a spectral resolution as possible. The characteristics of two of the instruments, the Hilger-Watts presently utilized on the TRAP-6 aircraft and the Barnes UV lens, are summarized in table I-15. A third lens system was also considered. This lens, to be designed to AERL specification, was deemed to be undesirable in terms of the higher total cost vs. an uncertainty of the final results.

From the specifications of the two instruments in table I-15, it would appear that the Hilger-Watts lens would be slightly more sensitive, 1.65 to 1, for unresolved streaked targets, whereas the Barnes instrument would have a greater angular coverage and a smaller physical size. We were able to obtain one of the Barnes lenses for testing so that a direct comparison between these two lenses was possible.

Two of the Hilger-Watts lenses were analyzed. The better of the two, #61, was used for all further comparisons with the Barnes lens. The other Hilger-Watts lens' poorer performance was probably due to surface irregularities in one of the lens elements and is not necessarily representative of this type of lens.

Figure I-23 shows the on-axis modulation transfer function for both of these lenses utilizing an interference filter to prevent chromatic shift from masking the results. While this wavelength region is not

TABLE I-15

UV STREAK SPECTROGRAPH

	Present System	Proposed System
Lens	Hilger Watts	Barnes
Focal Length	200 mm	105 mm
Diameter	57 mm	32 mm
Figure of Merit*	16.25	9.7
Resolution**		
Spatial	12 l/mm	35 l/mm
Angular	1.7×10^{-4} rad	2.5×10^{-4} rad
Fiew of View	20°***	3.8°
Camera	ASCM	Mauer 70 mm
Format	140 mm sq.	57 mm sq.
Framing Rate	Pulse 1 frame/sec 2 frames/sec capability	20 frames/sec
Framing Time	<.5 sec	
Spectral Characteristics		
Grating	300 gr/mm	600 gr/mm
Order	1st	1st
Linear Dispersion	166 A/mm	174 A/mm
Spectral Resolution	7 Å on axis	4 Å on axis
Angular Coverage	10° for zero order to .55μ	20° for zero order to .55μ
Boresight Error	± 5°	± 5°

* Figure of Merit for a streak camera (diameter)^2/ focal length.
** Resolution is given for the 20% modulation on axis.
*** 35° is total field possible but only 20° is useful due to lens vignetting.

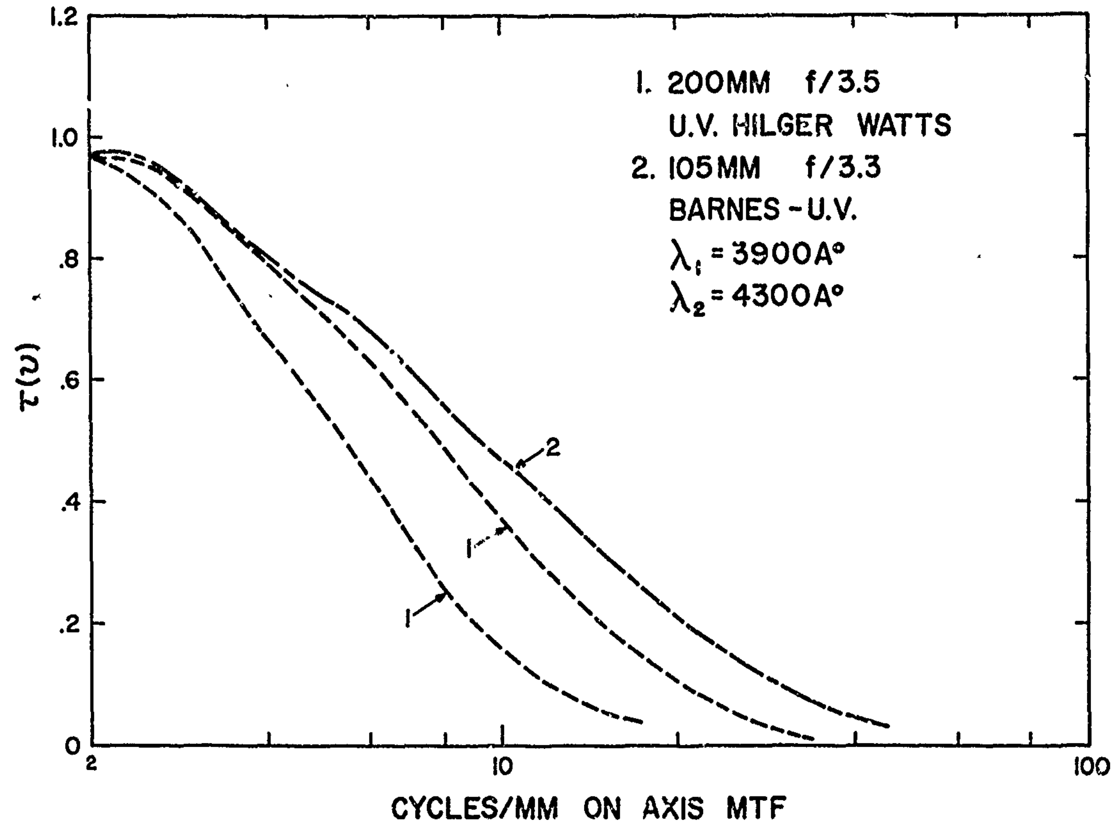

Fig. I-23 On-axis MTF for UV streak spectrographs.

optimum for either lens, it is well within the spectral bandpass we wish these instruments to record and serves as a reference point in discussing their characteristics.

Figure I-24 shows the lateral ray error for both lenses.

Both the MTF comparison and the lateral ray error plots indicate that the spatial resolution of the Barnes UV lens will be about 1.5 times greater than that of the Hilger-Watts lens.

For use as streak spectrographs, the angular resolution of both lenses must be considered also. The angular resolution of the Hilger-Watts lens is a factor of 1.5 better than that of the UV Barnes, recording 1.7×10^{-4} radians to the Barnes UV lens angular resolution of 2.5×10^{-4} radians. However, the lenses will be the cause of limiting resolution in both instruments so that when we multiply the lenses' sensitivity for streaked, unresolved targets both will have the same sensitivity while the Barnes lens still has a wider field of view and smaller package size.

For equal spectral resolution, the angular dispersion of the grating used with the Barnes lens must be increased to maintain the same spectral resolution. This can be done by utilizing a 600 groove per millimeter grating. Figure I-25 shows the proposed spectral format of the Barnes system compared to that of the present system.

Since the Barnes lens utilizes a 70 mm format, the Mauer 70 mm camera back has been chosen as a film transport. This transport allows a smaller physical size and less time between frames than the existing system, in addition to being a highly reliable, field-tested instrument. Mauer 70 mm camera backs are being used extensively in various field locations and provide the best possible choice of recording system.

The Barnes UV lens is an obvious improvement in our streak cameras, maintaining equal sensitivity with a greater field of view and smaller package size. An optimum system would consist of the 105 mm lens mounted onto a Mauer 70 mm camera back. A triple UV streak camera with a $38^{\circ} \times 106^{\circ}$ field of view is shown in figure I-26. This camera system is expected to be smaller in size than our present K-24.

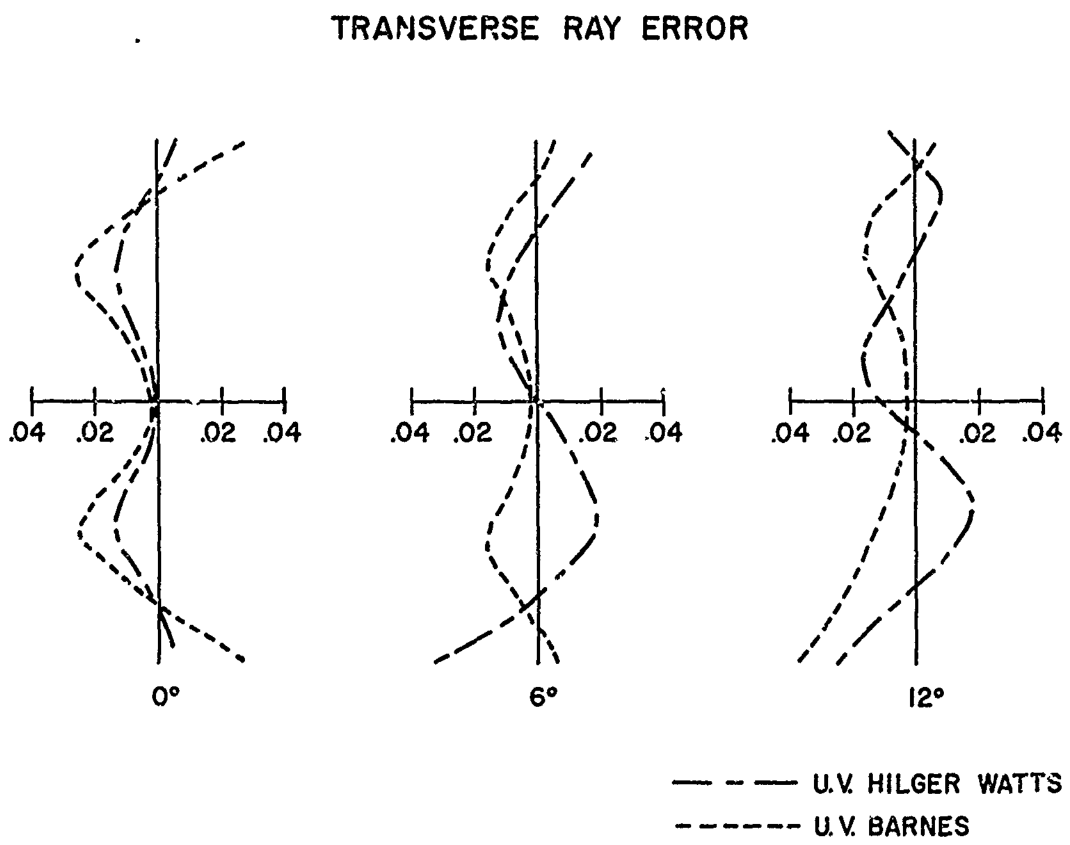

Fig. I-24 Transverse ray error for UV streak spectrographs.

R-8961

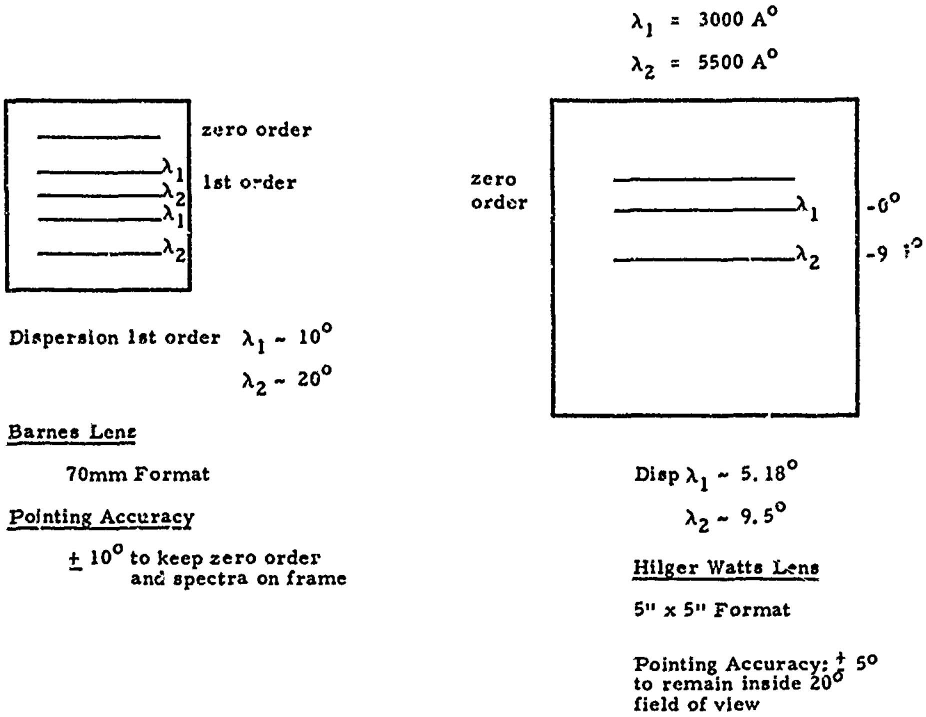

Fig. I-25 Format comparison for UV streak spectrographs.

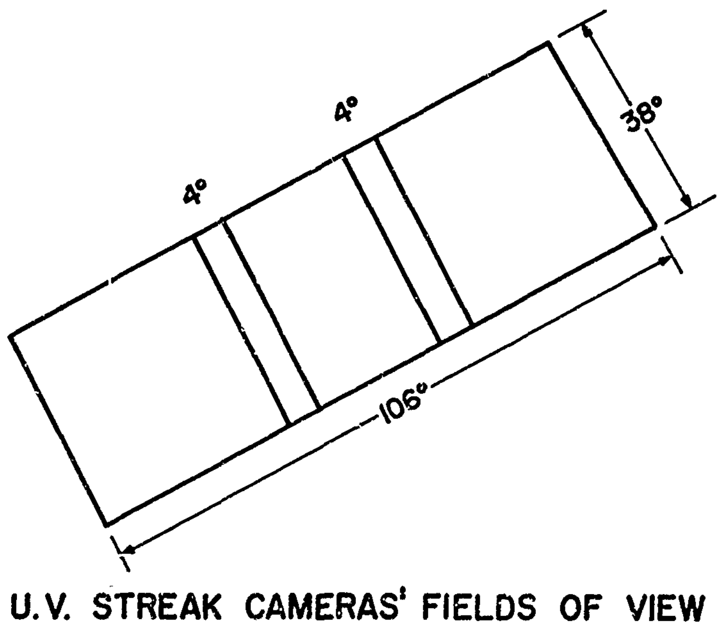

Fig. I-26 UV streak spectrograph field of view.

R-8959
R-8960

Visible System

A survey of possible lenses to improve upon the characteristics of the presently utilized Aero-Ektar was made, with the results tabulated in table I-16. The Zenotar 6" focal length f/2.8 lens produced the best results of the lenses tested and compares very favorably with the data supplied by manufacturers. Coupled with type 2475 film, this lens should produce the most sensitive streak instrument presently available. A 150 mm, f/0.86 lens investigated for this application was eliminated due to the severe mechanical difficulties imposed by a 0.025" lens-to-film sparing requirement which does not allow room for a focal plane shutter. The Astro-Berlin lens was eliminated due to its poor resolution past a 26° field angle, but it is an excellent choice for a narrower field-of-view instrument. A Peco 6" focal length f/1.5 lens was not included in the survey as it is designed for the IR and is not recommended for use as a visible lens. Testing of other lens systems, such as Kollmorgen, is currently in progress.

Comparison of the 150 mm f/2.8 Zenotar lens with the Peco lens of the same specifications shows that they are practically identical. Further information concerning the Peco lens is expected from the manufacturer, but it is doubtful that the Peco lens will show significant gain over the Zenotar to justify the high cost differential between the lenses.

Figure I-27 shows the MTF curves for the Zenotar lens and its expected performance across the field. The Zenotar lens was chosen over the apparently faster Astro-Berlin due to the poor resolution and field characteristics of the Astro-Berlin lens. It is expected that the increased resolution of the Zenotar will increase the threshold sensitivity of the instrument so that the proposed instrument will have a greater threshold sensitivity across its field of view.

Table I-17 shows a comparison of the characteristics of the present instrument and the characteristics of the proposed instrument.

Infrared Streak Spectrograph

These spectrographs will utilize a lens system focused for the infrared. Three lenses have been considered for these instruments to date. They are as follows:

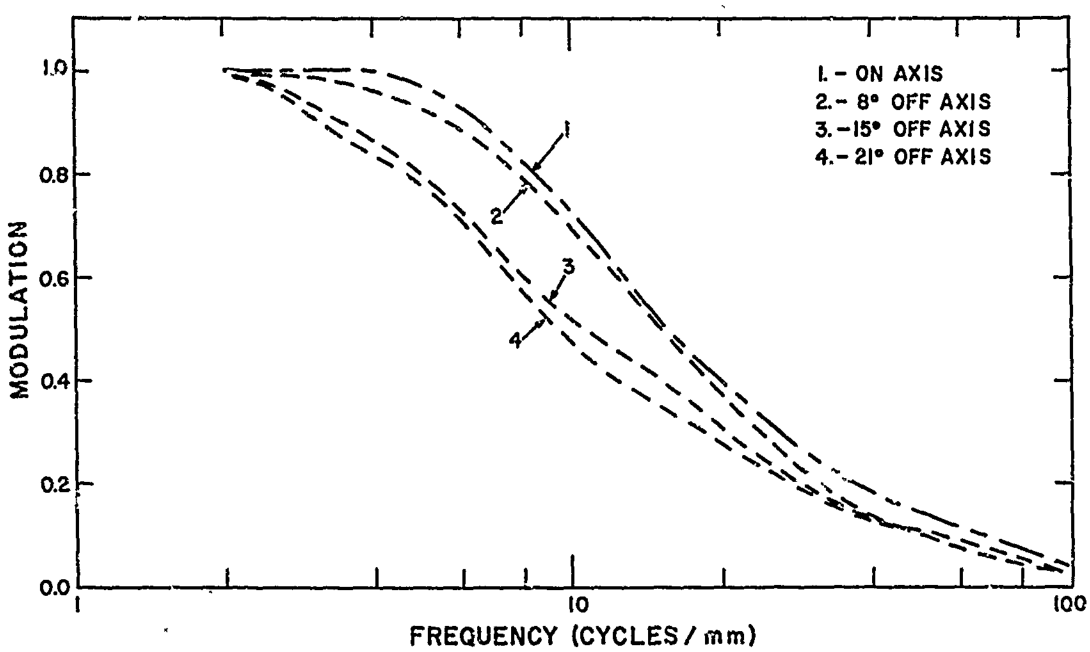

Fig. I-27 Modulation transfer functions for Zenotar Lens.

TABLE I-16

LENS COMPARISON FOR VISIBLE STREAK SPECTROGRAPH

Lens	Focal Length	Diameter	Figure of Merit	Resolution	
				MTF*	Film**
Peco***	150mm	53.6mm	19.15	-	75 l/mm AWAR****
Paxar	150mm	53.6mm	19.15	-	38 l/mm AWAR****
Zenotar	150mm	53.6mm	19.15	35 cycles/mm	80 l/mm on axis
Aero-Ektar	178mm	71.1mm	28.4	21 cycles/mm	35 l/mm on axis
Astro-Berlin	150mm	100.0mm	66.6	16 cycles/mm	25 l/mm

* MTF - Resolution at 20 modulation on axis

** Film - Pan-X

*** f/2.8 designed for visible

**** Manufacturer's specification - 75 l/mm AWAR Pan-X
50 l/mm AWAR Plus X

TABLE I-17

COMPARISON OF VISIBLE SPECTROGRAPHS

Lens	Aero-Ektar	Zenotar		
Focal Length	178mm	150mm		
Diameter	71.1mm	53.3mm		
Figure of Merit	28.3	18.9		
Resolution				
Spatial	21 cycles/mm	35 cycles/mm		
Angular	2.7×10^{-4} rad	1.9×10^{-4} rad		
Field of View				
($140mm^2$ format)*	38°	50°		
($114mm^2$ format)	36°	42°		
Camera	ASCM	Under Study		
Format	$140mm^2$			
Framing Rate	1 frame/sec 2 frames/sec poss.			
Framing Time	< .5 sec			
Spectral Characteristics				
Grating	300 gr/mm	600 gr/mm	600 gr/mm	500 gr/mm
Order	1st	1st	1st	2nd
Linear Dispersion	186 A/mm	93 A/mm	110 A/mm	66 A/mm
Spectral Resolution	8 A on axis	4 A on axis	3 A	1.8 A
Angular Coverage	11° first order	23° first order	23° first order	37°
Boresight Error	$\pm 13^{\circ}$	$\pm 6.5^{\circ}$	$\pm 14^{\circ}$	$\pm 6^{\circ}$
	$\pm 12^{\circ}$	$\pm 5.5^{\circ}$	$\pm 10^{\circ}$	$\pm 2^{\circ}$

* 42° is possible but only 38° is useful.

a. Zenotar

b. Astro-Berlin f/1.5

c. Peco f/1.5, 6"

Test data on the Astro-Berlin f/1.5 lens compares favorably with the data available on the Peco lens. Testing is being completed on both the Astro-Berlin and Zenotar lenses to establish which has the better characteristics in the photographic infrared. This test data will be compared with that obtained from Perkin-Elmer to reach a final decision on lens choice for the infrared streak spectrograph.

Field of View Considerations

Three instruments per wavelength interval are required to permit adequate coverage of the required field of view. Three instruments, rather than a single instrument on an indexing mount, are required due to planned re-entry configurations with multiple object re-entries, etc. Use of an indexing mechanism and a single instrument would lead to loss of data through its limited field at any given time.

Twin Spectral Ballistic

A Twin Spectral Ballistic will be utilized on the TRAP-1 aircraft. This instrument provides a valuable aid in data reduction by presenting the total uninterrupted spectral history of all objects. It also provides continuity to the framed spectral data and produces a qualitative gross overall evaluation of the spectral history.

The instrument is an AERL standard twin ballistic equipped with a transmission grating.

Cinespectrographs

Two gimbal mounted cinespectrographs will be utilized on the upgraded TRAP-1 system. These sensors are the Barnes cinespectrograph and the GE telespectrograph, the characteristics of which are discussed below.

Barnes Cinespectrograph.

The Barnes cinespectrograph is expected t , be a valuable addition to the TRAP-1 instrumentation complex.

The L-shaped instrument profile will present a mounting problem and will preclude obtaining the largest possible field of view. The calculated FOV outline based on preliminary design information is shown in figure I-28.

40" GE Telespectrograph

This instrument will be gimbal mounted and will provide higher resolution spectra than any other TRAP-1 spectrograph. The instrument will be evaluated with both the visible and infrared prisms and will have a field-change capability between prisms for mission flexibility.

An AZ/EL field of view plot for this instrument and its boresight camera is provided in figure I-29 and is computed from the anticipated mounting position relative to the window.

12" In-Line Cinespectrographs

The two GE in-line cinespectrographs will be evaluated upon receipt and are planned to be utilized on a manual pedestal. These instruments will provide a useful redundancy in cinespectrograph instrumentation. The 4^{o} field of view of these instruments does not require gimbal mounting.

High Resolution Sensor

A Jones 80" High Resolution 35 mm Camera System is under consideration for employment on a gimbal to produce spatially resolved details of wake and body luminosity history. Summary specifications of this instrument are presented in table I-13 with a field-of-view plot shown in figure I-30. This field of view plot shows the no vignetting AZ/EL contour for the Jones telescope and boresight camera. This plot is computed from the anticipated mounting position relative to the window.

Intensity Sensors

Inasmuch as the Barnes two-color radiometer and the atomic line radiometer are under procurement under the existing contract, their merits have been well documented in the past. These instruments will be mounted on gimbals in the locations shown in figure I-22.

Other Sensors

Details on the proposed Fabry-Perot Etalon Spectrometer shown at window 5 (fig. I-22) and the Image Intensifier System shown at windows 4 and 7 are presented in task 4.0 of this Semi-Annual Report.

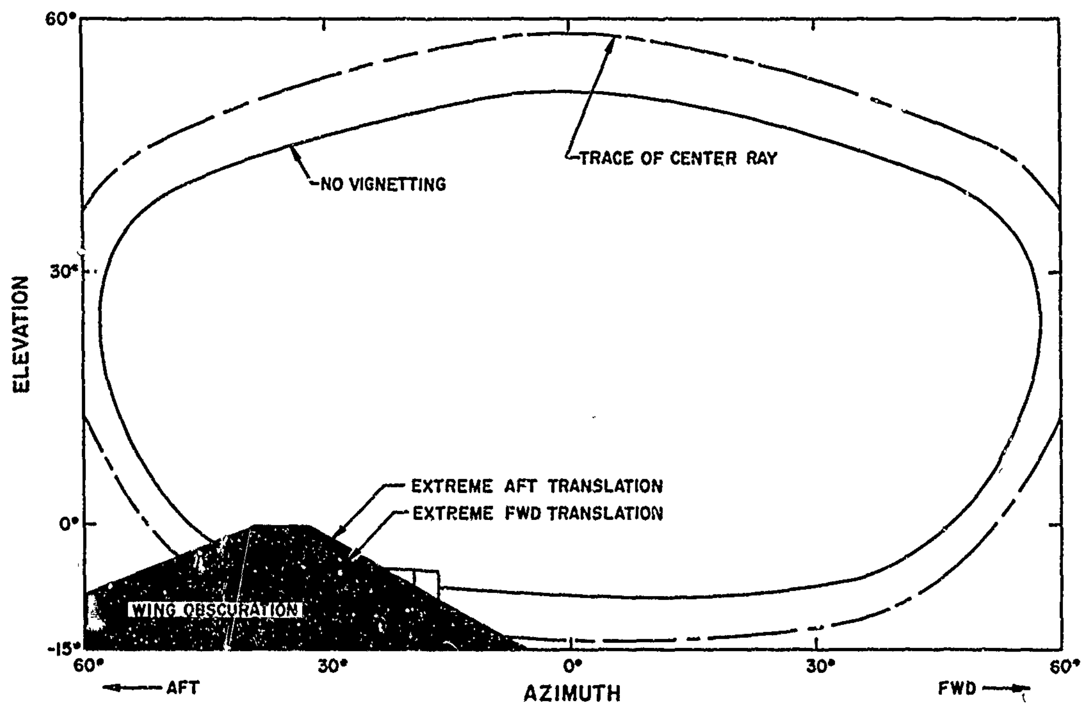

Fig. I-28 Field of view plot for Barnes cinespectrograph.

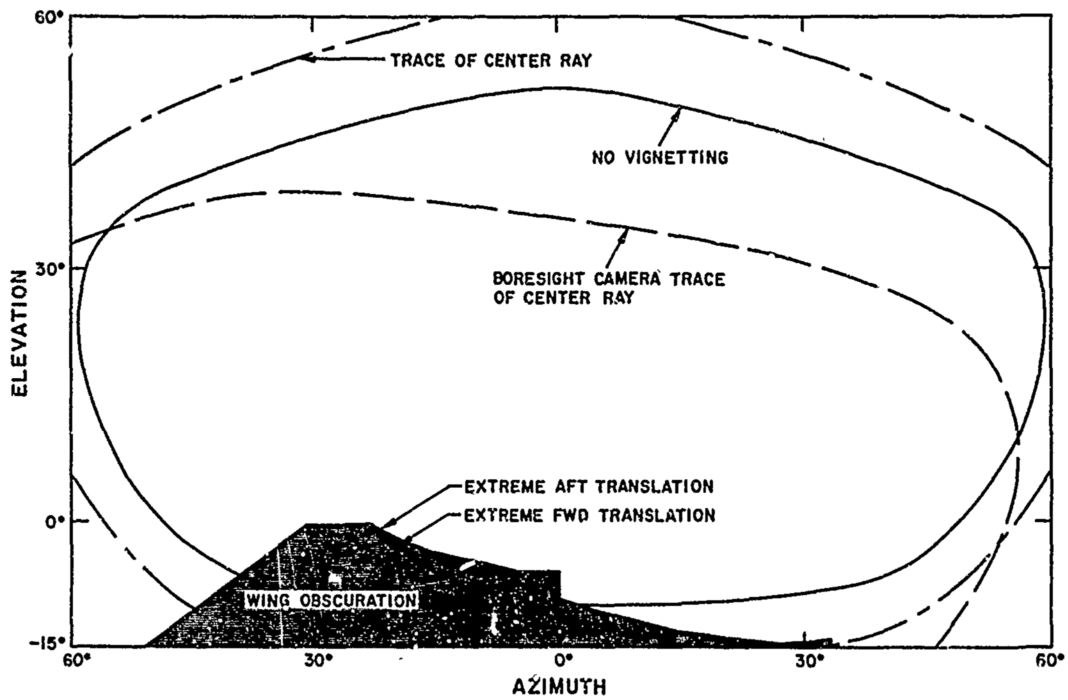

Fig. I-29 Field of view plot for 40" Telespectrograph.

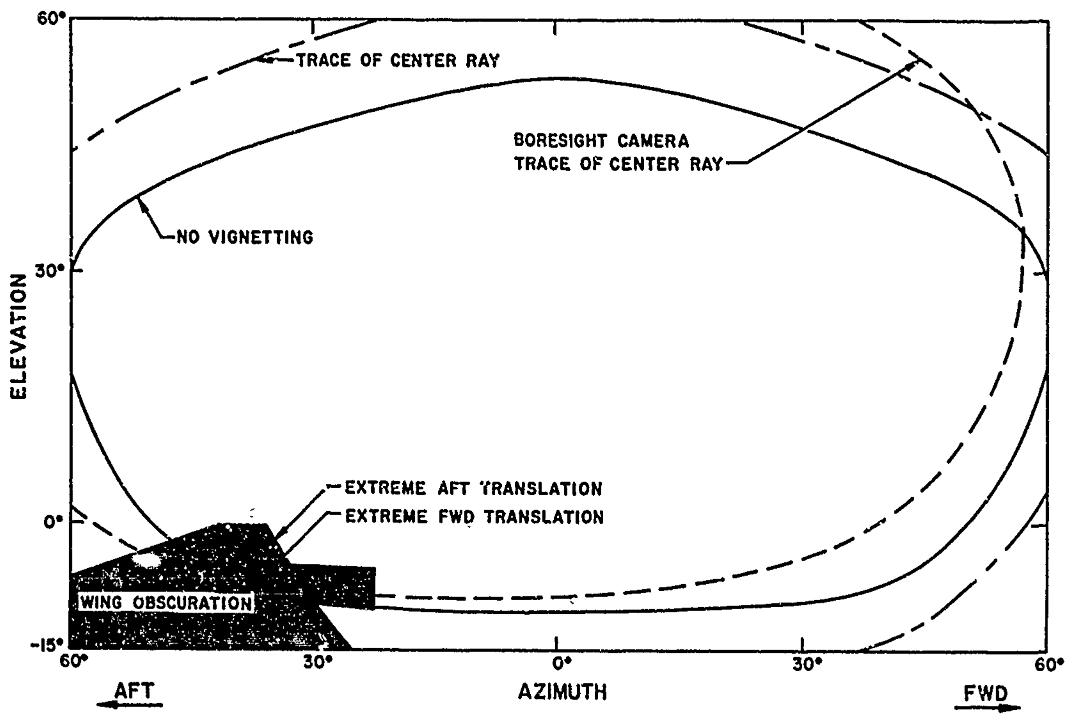

Fig. I-30 Field of view plot for 80" Jones Telescope.

Boresight Cameras for TRAP-1

Where feasible, the payload of each gimballed pedestal and each manual pedestal will include a 16 mm cine camera for the purpose of providing a convenient record of the target appearance and its location with respect to the pointing axis of the pedestal. This record will greatly facilitate the analysis of the data from the primary instrument on the pedestal. Furthermore, the record will provide an additional means for evaluating the tracking performance of the pedestal.

In order to be useful, it is desirable that the boresight camera have a higher degree of steadiness than the gimbal itself. In many cases, it is desirable to detect jitter amplitudes of approximately 0.1^{o}. For this purpose, the unsteadiness of the camera itself should be limited to about 0.02^{o}. For a camera with a 4" lens, this would require a framing accuracy of 0.0015". This degree of accuracy would seem to indicate the need of a "pin-registered" type of camera or one of equal performance. However, presently used pin-registered cameras are sometimes too large to fit into a gimbal configuration with enough clearance for use of the boresight tool, access for loading, etc. Consequently, a survey was undertaken to determine what small cameras are available and what framing accuracy can be achieved with them. Table I-18 lists the characteristics of some of the cameras considered in this survey.

A measure of the framing accuracy was not available from the manufacturers in all cases. However, certain manufacturers expressed a willingness to provide a sample film which we could use to measure steadiness ourselves. Final selection of boresight cameras will be accomplished after analysis of these films are complete. The type of measurement made in this analysis is shown in figure I-31. The sample plots in the figure show vertical registration measurements made on two currently used cine cameras. In each case, the camera was clamped to a platform facing a point source and run at its maximum framing rate. The resulting film was then measured frame by frame to determine the variation in image location with respect to the perforations.

TABLE I-18

CHARACTERISTICS OF 16 mm CINE CAMERAS

Manufacturer	D. B. Milliken	D. B. Milliken	D. B. Milliken	Mitchell	Traid	Traid
Model Designation	DBM-3C	DBM-25	DBM-2A	HS-16-F2	KB-3A (GSAP)	Fotopak/15
Weight	7 3/3 lbs.	4 1/2 lbs.	2 lbs.	8 lbs.	3 lbs. 13 ozs.	2 lbs. 5 ozs.
Size L x W x H	6.7 x 4.4 x 5	7.4 x 3 x 3	6.2 x 1.9 x 3.3	7.8 x 4.2 x 5.7	6.3 x 2.4 x 3.4	5.2 x 3 x 4.5
Film Load	100'	50'	50' - 100' Mag.	200'	50' or 100' Mag.	50' Mag.
Timing Lights	yes-dual	no	no	yes-dual	yes	yes
Lens Mount Type	"C" Mount	"C" Mount	Special	"C" Mount	"C" Mount	"C" Mount
Shutter Type	Fixed Rotary	Fixed Rotary	Fixed Rotary	Fixed Rotary	Adjust. Rotary	Adjust. Rotary
Pin Registration	yes	no	no	yes	no	no
Framing Rates	64, 200, 128, 400	16-32-64	16 or 32 Fixed	Contin variable	16-24-32-64	16-100 Fixed

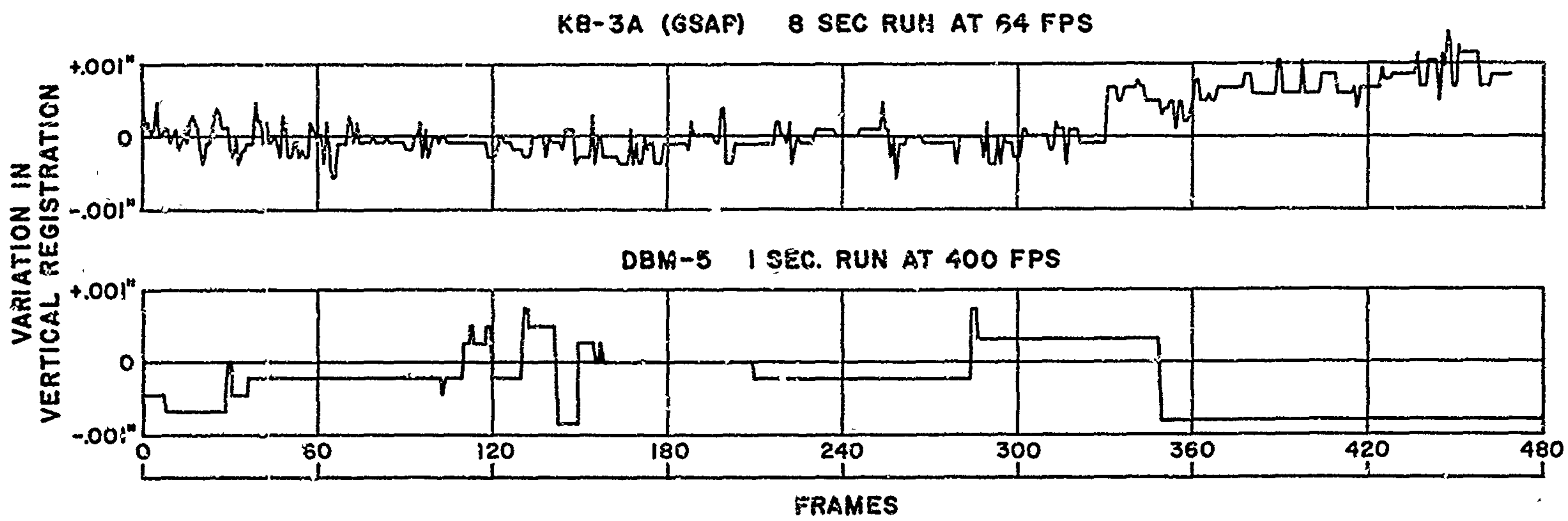

Fig. I-31 Vertical registration plots for two Boresight Cameras.

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Boresight Shutter

Associated with each radiometer in the system will be a boresight camera. In order to reduce the radiometric data effectively, it is important to establish a representation of the radiometer field of view on the boresight film record. The "Boresight Shutter" is a device which provides this capability accurately and with a high confidence level.

The device is a simple attachment consisting of a solenoid actuated shutter which is temporarily installed in front of the boresight camera lens as shown in figure I-32. The solenoid is powered by the output signal of the radiometer. As the pedestal is panned back and forth across a distant target, the shutter is opened automatically only when the target is within the field of view of the radiometer and the boresight camera records the target. The resulting record is a series of lines defining the field of view of the radiometer recorded on a single frame of the boresight film.

An important advantage in this approach is that the relationship between the radiometer and the camera is known to a high degree of accuracy without the need of a great deal of precision during the installation. Measurements indicate that the field of view can be established readily to 2%, or 0.04° in the case of a 2° radiometer.

Implementation of this concept is underway on a BTL-sponsored program. A system has been installed on the EC-121K aircraft and is now in the field evaluation phase. The same basic design appears applicable to the TRAP-1 program with modifications to suit the particular payload configurations.

Interim System

Prior to the completion of the upgraded system components previously discussed, the TRAP-1 aircraft will be equipped with an interim system. This system will be provided from currently available equipment and such new equipments as can be feasibly phased in during the interim period of operation. Figure I-33 shows the final interim system installation. An existing Aeroflex gimbal system will be utilized in the interim system as well as in the upgraded system and will provide an automatic tracking capability for the TRAP-1 platform in its initial configuration.

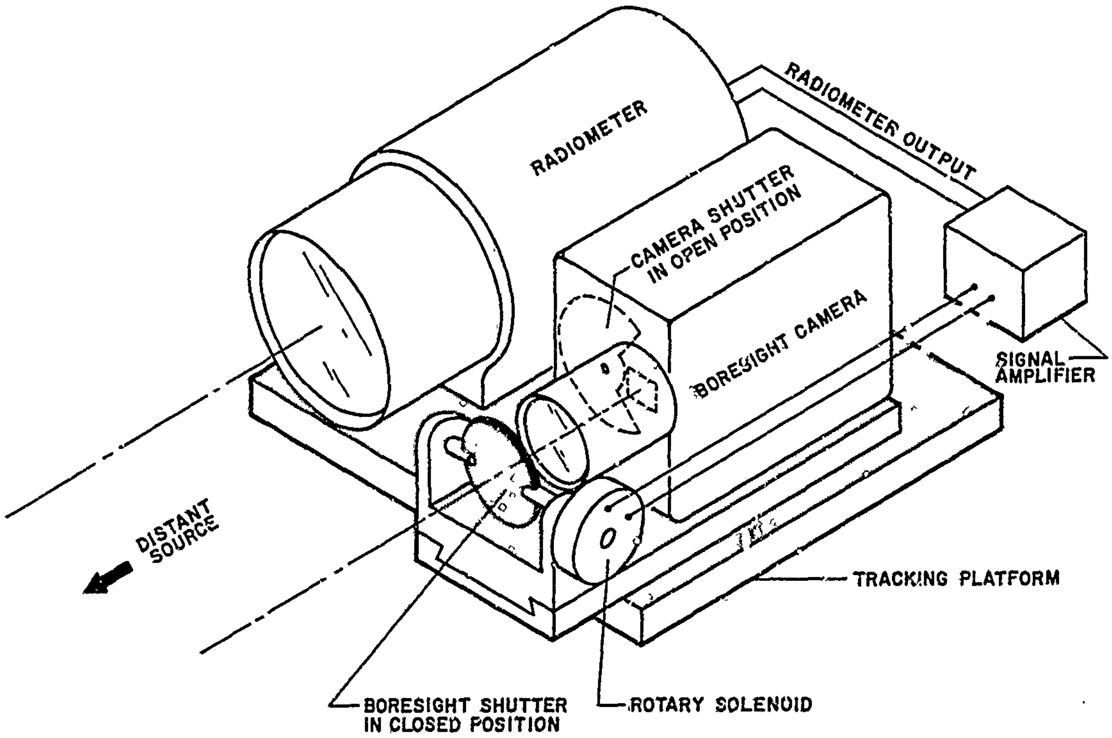


Fig. I-32 Boresight shutter attached to Boresight Camera.

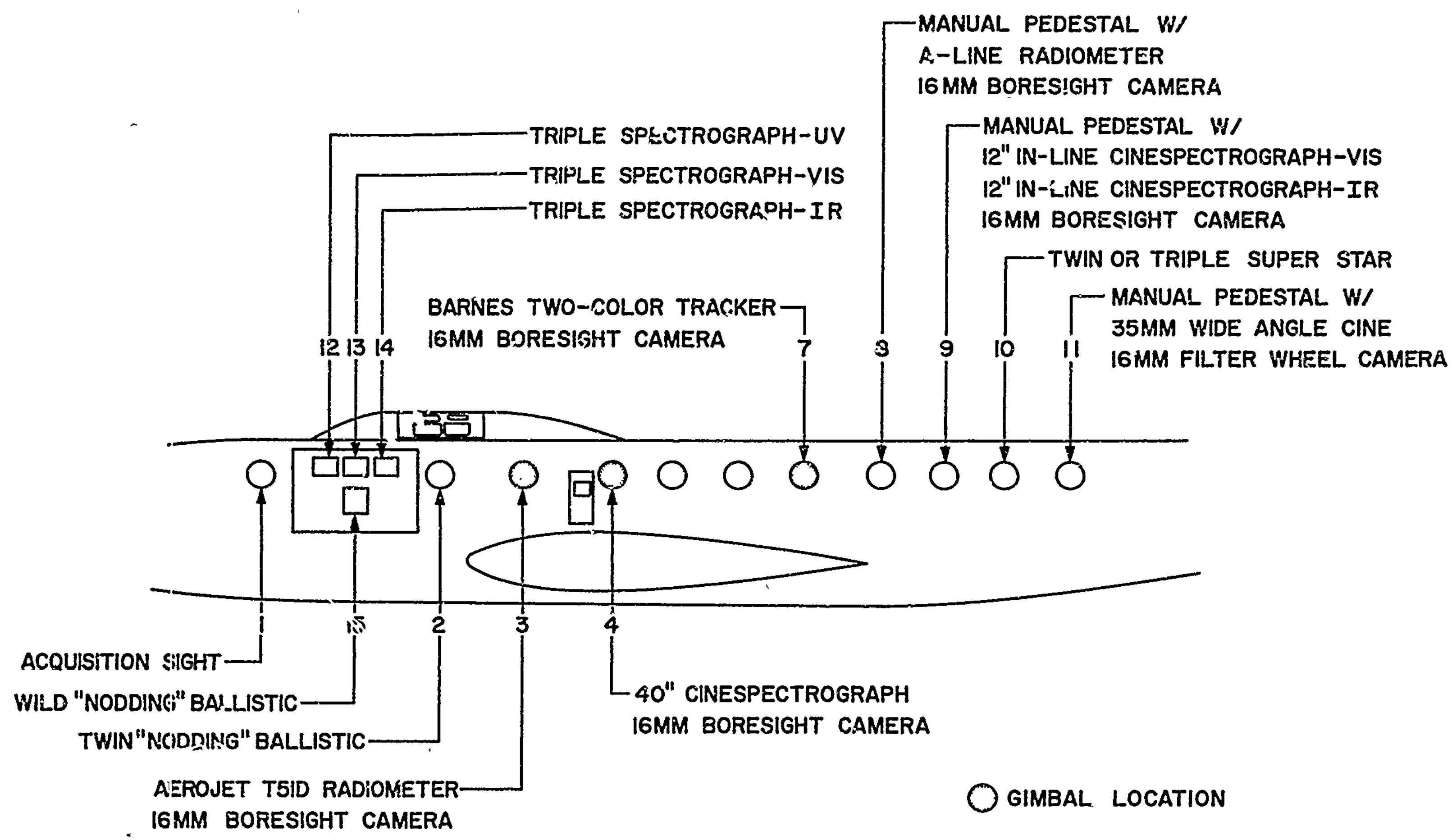


Fig. I-33 Interim TRAP-1 configuration.

Pointing Subsystems

The major support elements of the TRAP-1 sensor matrix are the pointing subsystems. These subsystems consist of the following primary components:

a. Acquisition Sight Pedestals
b. Master Tracking Pedestal
c. Slave Pedestals
d. Manual Pedestals

The preliminary configuration of these components is shown in figure I-22. This arrangement is based on one master tracking pedestal, five slave pedestals, two acquisition sight pedestals, and two manual pedestals.

The system will be capable of acquiring a desired target by using a manual acquisition sight pedestal. The master tracking pedestal will have mounted on it an optical error sensor for developing servo errors. These signals will be used to automatically track the desired target upon command or can be switched automatically from acquire to track.

A system block diagram for the gimballed pedestals is shown in figure I-34. Only one master tracking pedestal and acquisition sight pedestal is shown with six slave pedestals commanded from either source. The exact array will be determined prior to each mission with appropriate switching to arrange the array as desired. Switch positions, indicated by 1 and 2, allow presetting fixed angles for standby and fixed line of sight (FLOS) respectively. Switch position 3 allows slaving all pedestals including the master from the acquisition sight pedestal. The basic system is capable of commanding up to nine slaved pedestals.

Master-Slave Array

Design provisions will be made for a capability of employing two master gimbals rather than only one. This will be accomplished by reconfiguring one of the five slave pedestals with an automatic tracker and position transducers capable of pointing a preselected number of slave pedestals. Both master tracking pedestals with their respective

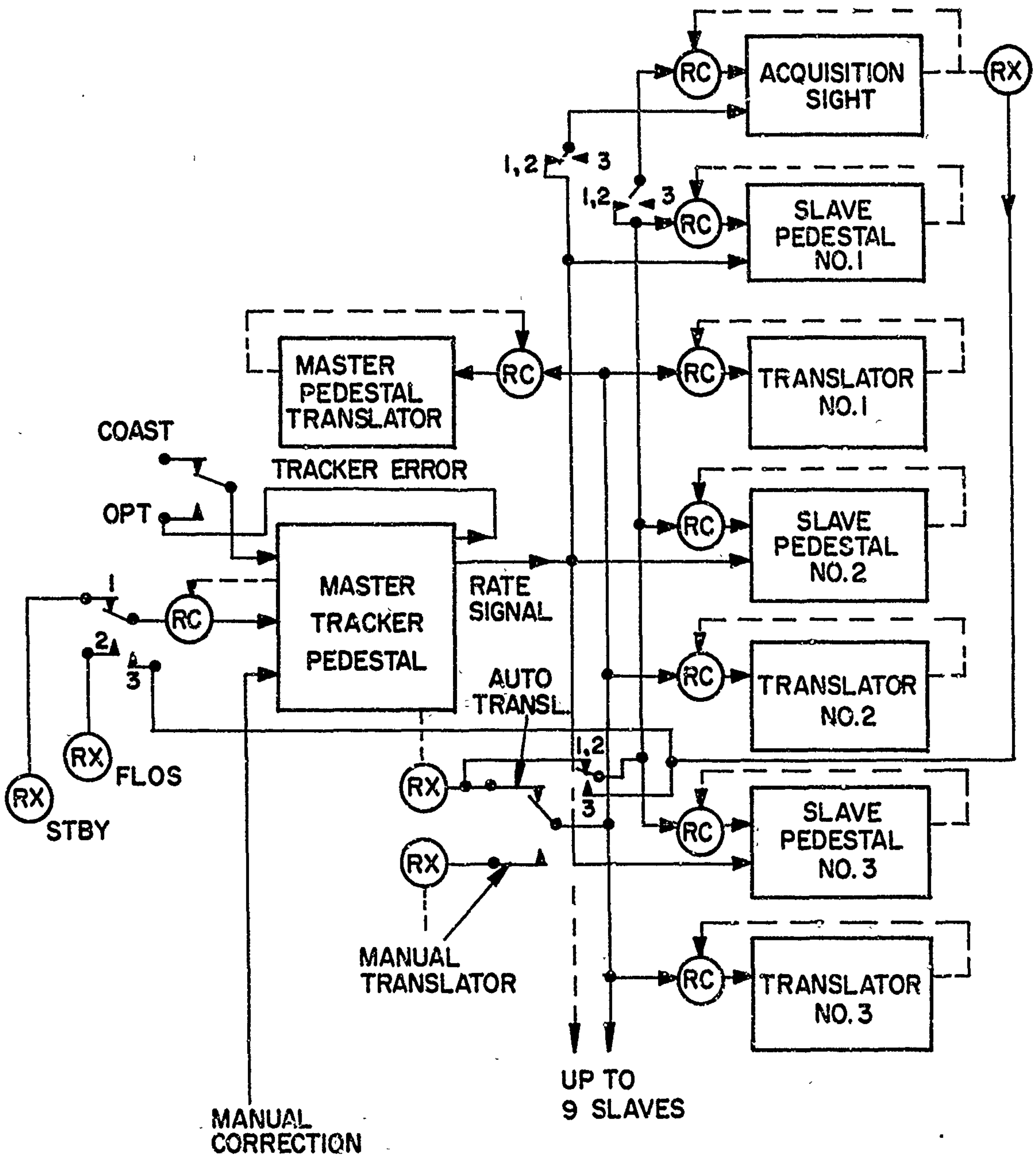


Fig. I-34 System block diagram for TRAP-1 Gimballed Pedestals.

R-8436

slave pedestals can be pointed independently of one another. Each pedestal will be capable of pointing an inertial load of 3.5 slug-ft^{-2} whose weight does not exceed 150 pounds including an appropriate counterweight.

All gimballed pedestals will be inertially stabilized and decoupled from aircraft dynamics including relative aircraft structural dynamics. Vibration and shock isolation will be provided for all pointing subsystem components to insure component and instrument saf-ty as well as for decoupling aircraft perturbations from the pointing system.

The design of the pointing system will include on-line diagnostic aids for monitoring system performance during missions. These will include angular position and rate transducers and servo error generators. The recording devices for on-line diagnostics will include multichannel strip chart recorders and CRT's. For off-line diagnostics of system performance, these signals will also be recorded on magnetic tape by the data acquisition and recording system. Additional off-line diagnostics will be provided by reducing the normal mission boresight data as recorded on film. The position transducers will be incremental optical encoders with 16-bit (19.8 arc-sec) resolution. This resolution will allow position correlation of all pedestals to within 20 arc-sec.

Acquisition Sight Pedestals

The acquisition sights will have two angular degrees of freedom for rotating in azimuth and elevation. Position transducers will be provided for remote positioning of up to ten preselected gimballed pedestals, including the master tracking pedestal, onto the selected target. The total error signal between the line of sight of the acquisition sight and the remotely pointed pedestal line of sight will be within one-half degree assuming that inputs to the acquisition sight do not exceed 15 degree sec^{-1} and 3 degree sec^{-2}. An integral part of these pedestals will be mode control switches for switching from manual control to automatic track. The inner gimbal will be designed to allow adaptability to new acquisition aids in the future.

These pedestals will be equipped with servo-assisted drives to facilitate their pointing when being directed to the target line of sight by the master tracking pedestal during the automatic tracking mode. Capability will be provided for manual correction of the master tracking pedestal prior to automatic tracking, and an override of automatic tracking will be provided at these stations.

When automatic track cannot be achieved, the acquisition sight pedestals will be pointed manually. All pedestals will be capable of being pointed by the acquisition sight pedestals in this mode.

All servo-controlled pedestals to be used for pointing instruments during a re-entry will have two angular degrees of freedom and one translational degree of freedom. This configuration will make optimum use of the aircraft windows considering instrument fields of view. Instruments will be mo nted on the inner gimbal. Design of the gimbal will be consistent with state-of-the-art and will have maximum adaptability and flexibility to future expansion and instrument assignment.

Translation of the gimbals will consist of plus and minus 15 inches of travel in the fore and aft direction. The field-of-view coverage of typical instruments mounted on these translating gimbals has been shown in figures I-28 and I-35. The field of view coverage is limited by the distance that the instruments (thus the axes of rotation) must be kept from the window to maintain adequate clearance.

Rotational and linear motion of the gimbals in its three axes will be limited mechanically by stops designed to dissipate the maximum possible stored energy. These stops will be designed with maximum consideration given to the safety of instruments mounted on the gimbals.

Shock and Vibration Isolation

The function of shock and vibration isolation for the TRAP-1 gimbals is twofold. The first is to minimize instrument image blurring caused by aircraft disturbance motion. One such motion will arise through aircraft linear vibration coupling through cg offsets of the optical instrument package attached to the gimbal.

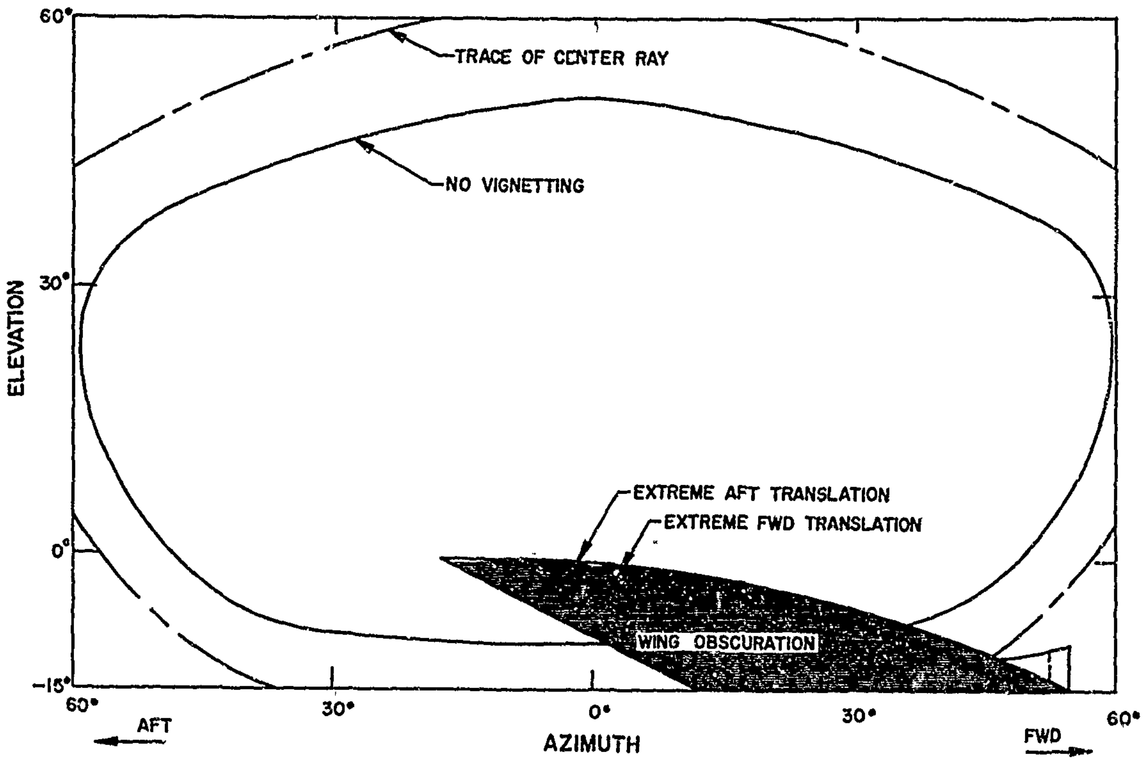


Fig. I-35 Field of view plot for A-Line Radiometer.

The second vital function of the isolation system is to prevent aircraft shock and vibration from damaging an optical instrument. This precaution must be taken so that future optical instruments (not necessarily designed to MIL-E 5400 or MIL-E 5272) can be successfully flown aboard the TRAP-1 aircraft.

Undesirable coupling that degrades image quality can arise from at least four different sources. These are:

a. Shock mounts having different gradients

b. Total platform cg offset

c. A gimballed element cg offset

d. Gyro unbalance

The first two items produce a base rotation that couples into gimbal motion through bearing friction and torque motor back emf. Back emf coupling will be minimized through use of current amplifiers to drive the gimbal torque motors.

Cg offsets of the gimballed elements can be reduced to a minimum, but never completely eliminated. Under field conditions, changing an instrument package while retaining the gimbal balance is a difficult task. It is this source of vibration error that the servo system must minimize. This is accomplished by having the servo attenuate the low frequency disturbance with the vibration isolators eliminating the high frequency disturbances. Rate integrating gyros are an important feature for this isolation.

Gyro sensitivity to acceleration is 24 deg/hr/g maximum. This corresponds to 0.1 (mrad/sec)/g. For no isolation whatever and the peak acceleration (± 2 g's) of the KC-135 survivance test envelope, the maximum relative rate error will be only 0.2 mrad/sec. Under tracking conditions, the error should be negligibly small.

Use of shock mounts does introduce additional uncertainties into the pointing accuracy. These uncertainties arise from shock mounts with different gradients and shock mount hysteresis. The former will be minimized by an in-flight boresight procedure. The latter will be minimized by design and testing.

Vibration Isolation Summary

1. Effects of platform rotation about the shock mounts will be minimized through use of high output impedance amplifiers to drive the gimbal torquers.
2. Servo loop and shockmount bandwidth will be chosen to minimize disturbances from optical instrument cg offsets. Rate-integrating gyros provide an inertial reference to achieve this isolation.
3. Gyro drift errors from vibration will be negligibly small.
4. Steady-state pointing errors resulting from use of shockmounts will be minimized by inflight boresight alignment and use of low hysteresis shockmounts.

Optical Error Sensor

Mounted on the master tracking pedestal will be an optical error sensor capable of tracking the re-entry target once it has been acquired and discriminated from the background and from other objects in the re-entry complex. Automatic tracking will be accomplished by using the errors generated by the optical error sensor as the input to the master pedestal. This will provide accurate tracking of selected targets at specified target kinematics in the presence of a night sky background. Capability of automatically narrowing its field of view after initial acquisition will be provided including an override of this same feature.

For many years, the best proven performance for optically tracking re-entry objects has been obtained from the Barnes Engineering Company error sensor Model 21-122C. AERL is intimately familiar with this unit and was instrumental in the modifications which have in recent years brought improved performance with the Model 21-124C.

The major system parameters are as follows:

Tracking Sensitivity	$\sim 5 \times 10^{-14}$ watts cm^{-2}
Pointing Accuracy (at S/N of 10:1 referred to 25 Hz BW)	0.1 millirad.
Error Signal Drift	0.1 millirad in 4 hours
Field of View	Selectable: 2° and 0.5°

Size:	
Optical Unit	11 in dia. x 21 in length
Electronics Unit	10.5 in high (in 19" rack)
Weight:	
Optical Unit	35 lbs
Electronics Unit	30 lbs
Power Input	
Voltage	115 VRMS
Frequency	400 Hz
Power	150 watt max
Power Factor	0.8 min

Although the initial intention was to use this sensor, it has become apparent that a new class of proven optical error sensors has become available due to the star tracking requirements of space probes and satellites. As a result, AERL is investigating the availability and capability of these new optical error sensors and their applicability to our tracking requirements. Preliminary evaluation of proposed equipments indicate a state-of-the-art device does exist. The important features of the proposed device are:

1. Low volume and weight
2. Low power consumption
3. Automatic field of view switching after acquisition Field of view during track is smaller to improve sensitivity and discrimination
4. High signal to noise ratio
5. Electronic scan of photo conductive sensing element
6. Electronic circuits comprised of integrated circuits

The other salient features of this type of tracker are the improvement of background discrimination because of the electronic signal processing technique. By using a high frequency TV type scan, filtering can smooth the sampled data with no decrease in total sensor bandwidth, thus decreasing system noise. Signals from the sensor can be used for CRT inputs to display the field of view of the tracker with the target and background included. This display should enhance acquisition and also provide additional on-line monitoring of tracking performance.

The final selection will be made between all of these devices based on optimum system performance. In any case, the performance will equal or exceed that shown above.

Manual Pedestals

Two manual tracking pedestals are included in the system for the purpose of providing versatile tracking platforms, with adequate tracking accuracy for instruments of approximately 2^{o} field of view or larger. Their design will permit convenient rearrangement of payloads when new instruments are to be added.

The instrument payloads for one of the manual pedestals will be arranged in a manner such as that shown in Figure I-36. The exact arrangement will be determined after careful consideration of loading accessibility, clearance for boresight tools, etc.

The pedestal design will be patterned along the lines of similar platforms formerly used on the TRAP-1 A/C and on the TRAP-6 A/C. In both cases the design has proved successful for pointing instruments of 2^{o} field of view. Evidence of this performance is shown in two figures which are reproduced from Research Note 612 entitled "TRAP-6 Radiometry Study Program." The first figure, Figure I -37a is a plot of manual tracking proficiency for various fields of view. Proficiency is defined in a manner which indicates the percentage of time that the target stayed within various circles of specified size. The second figure, Figure I -37b is a plot of tracking error measurements made from a boresight film record, and illustrates the performance of an experienced operator. From either of these figures it can be seen that manual pedestals of this design are well suited to instruments of 2^{o} field of view or larger. Furthermore, this evaluation may be considered conservative for the TRAP-1 installation because the operator will not be subjected to the buffeting conditions at an open door, as were the conditions for the above data.

An illustration of the design concept to be employed on the two manual pedestals is shown in Figure I - 38. The essential component in the design is a tracking head such as the O'Connor Head, which is provided with fluid damping for smooth tracking in both the azimuth and elevation axes. The vertical or azimuth axis of the head is located almost under the center of the

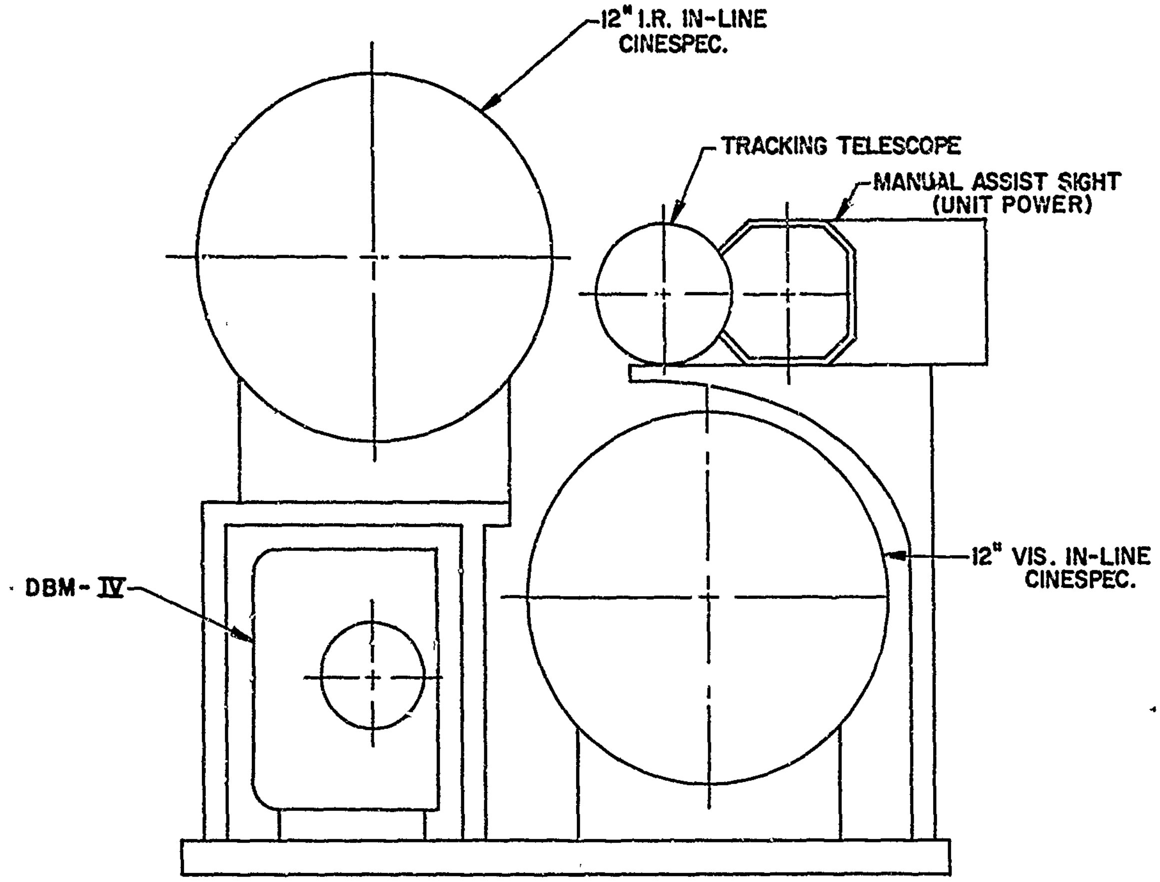
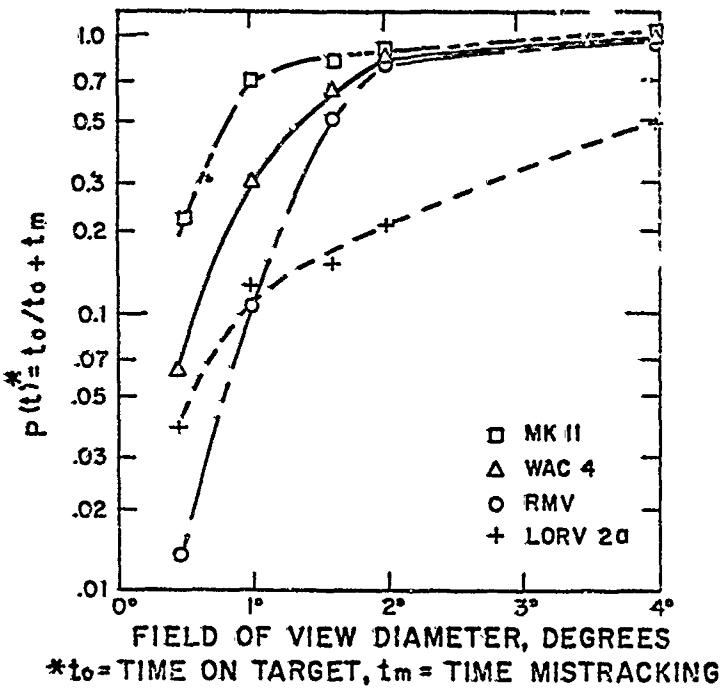


Fig. I-36 Payload configurations for manual pedestals.

A



B

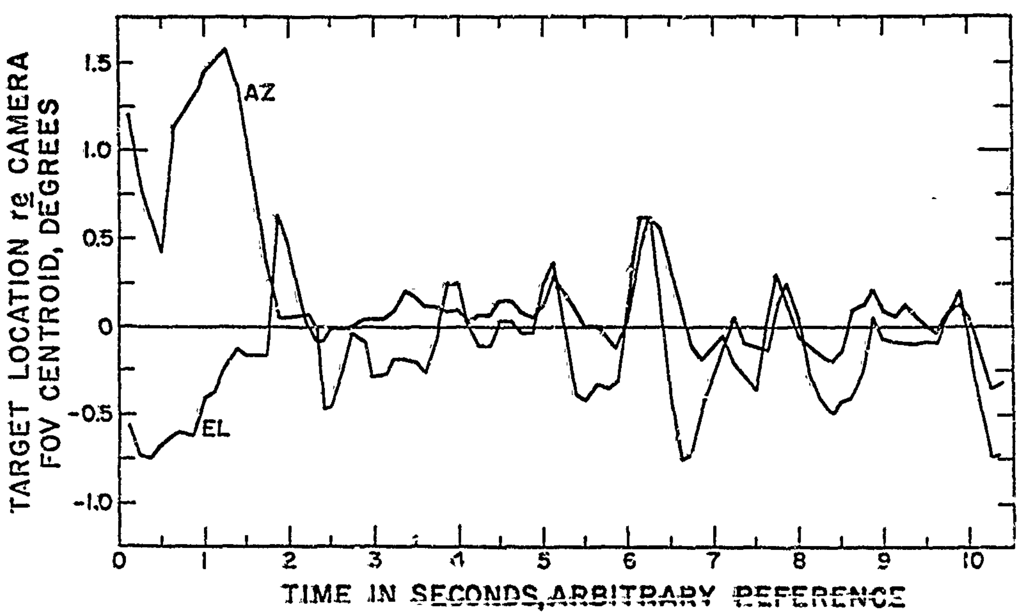


Fig. I-37 Manual tracking test data.

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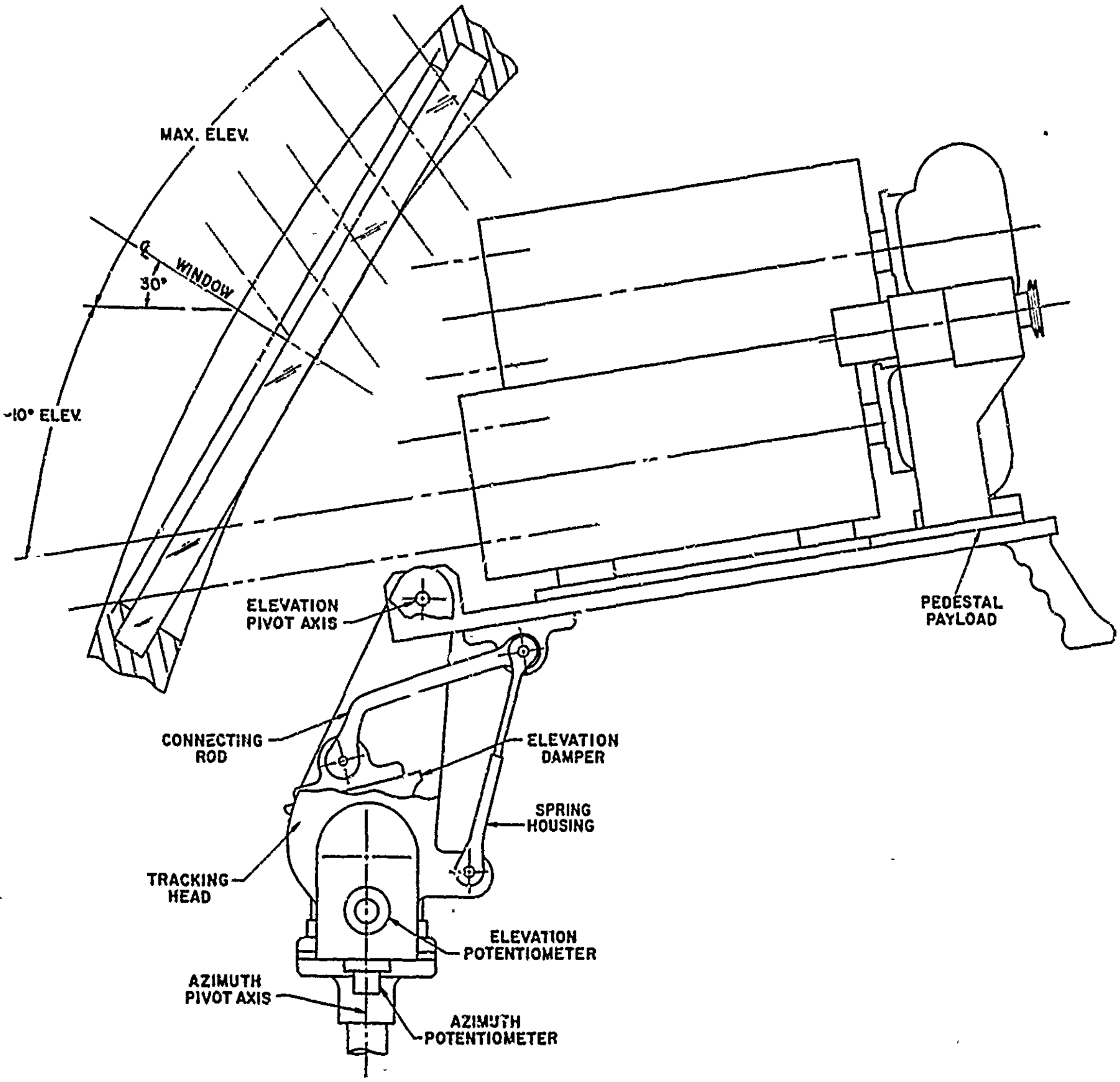

Fig. I-38 Side view of manual pedestal.

sloping window in order to provide maximum azimuth coverage through the window. Likewise, for maximum elevation coverage, an elevation pivot is provided as close to the center of the window as possible without causing interference with the line of sight of the instrument payload. In order to utilize the fluid damping action of the tracking head, a connecting rod is used to couple the instrument mounting plate to the elevation damper.

This pivot arrangement maximizes azimuth and elevation coverage, but also creates a cantilevered payload. In order to counterbalance the payload, a spring housing with compression springs is required. An arrangement similar to this has been in use for quite some time on TRAP-1 with good results obtained.

The pedestal configurations will include certain important components of the Assisted Manual Tracking System. This system is described in RN 592 by J. Foust, et al, entitled, "An Airborne Pointing System." The AMTS system makes it possible for the operator to follow a pointing input supplied by a master gimbal. The pointing input is displayed to the operator by means of crossed meter needles superimposed on the reticle of the tracking sight. In operation, the operator keeps the crossed needles centered on the reticle in order to follow the pointing input, while at the same time, he can observe the target within the tracking reticle.

The difference in pointing angle between the master gimbal and the manual pedestal establishes the pointing input to the operator. In order to provide a means of measuring the pointing angle of the manual pedestal, the O'Conner Head must be modified to accept potentiometers connected through gearing to the azimuth and elevation axes. In Figure I-38 this addition is contained in the housings attached to the lower portion of the tracking head. In addition, the manual pedestal pointing angles will be recorded for analysis of manual tracking performance.

In addition to the unit power sight with the crossed needle display, it has been found helpful to provide a tracking telescope with a certain amount of magnification. The telescope is mounted along side of the unit power sight at the proper interocular separation so as to enable the operator to look through both sights simultaneously. The telescope increases the apparent brightness of the target and magnifies the tracking error. Unfortunately,

increased magnification in the telescope is achieved at the expense of field of view. This trade-off is discussed in RN 638 by R. Prescott entitled "Visual Aids in Acquisition." A suggested compromise is in the region of 3 power and 20° field of view. As a result of this recommendation a 3 power sight was recently constructed for comparison with the 7 power sights presently in use.

Manual Pedestal Look Angles

Of the two manual pedestals, the one containing the 12" In-Line Cinespectrographs has the more restricted field of view. At 0° azimuth, the primary instruments will cover an elevation range from -10° to + 50° with no vignetting. At 0° elevation, the pedestal will rotate up to ±52° in azimuth before the payload touches the airframe. Stops will be provided to avoid contact with the airframe. However, at this angle, the 27" width of the window is foreshortened causing approximately 50% vignetting of the forward instrument when pointed forward and 50% vignetting of the aft instrument when pointed aft.

Data Acquisition and Recording System

This section will discuss the subsystems which together comprise the Data Acquisition and Recording System. One subsystem complements the other by collecting data in redundancy and neither one may be taken to replace the other since each has its own particular function. The analog recording system may be regarded as a completely passive system in that its primary purpose is to collect data, while the digital subsystem is both passive and active because it is capable of collecting data and can act as a controller. The overall system design is directed toward reliability and flexibility for future needs.

Analog Recording Subsystem

The functions of the analog recording subsystem are to provide both a primary and a redundant method for collecting and recording data from the sensors and timing system. The system design which is based upon these considerations is also applicable to future expansion and to additional input assignments.

Formulation of the requirements for the analog recording subsystem provides an indication for the direction of design. The system will be of

proven airborne construction adaptable to the possible future needs of expansion, and sufficiently flexible to include new input assignments. The design will have the capability for providing additional channels plus sufficient bandwidth to accommodate the outputs of foreseen instruments.

The equipment selected for use on the TRAP-1 platform is a Mincom PC-500 record/reproduce 14-channel system. This unit combines the flexibility of extended wideband coverage with a multichannel capability. AERL has recently purchased and installed such a unit on the BTL funded EC-121K aircraft. Solid-state, modular-type circuits and a coaxial reel assembly are combined to yield a compact assembly. The specifications for this unit are summarized below.

Mincom PC-500 Specifications

Start Time: 8 seconds at any speed

Frequency Response:

Tape Speed (ips)	FM System	Direct System
120	0 to 500 KHz ± 1 db to 200 KHz < 6 db down to 500 KHz	400 Hz to 1.5 MHz ± 3 db
60	0 to 250 KHz ± 1 db	400 Hz to 750 KHz ± 3 db
30	0 to 125 KHz ± 1 db	400 Hz to 375 KHz ± 3 db
15	0 to 62.5 KHz ± 1 db	400 Hz to 187.5 KHz ± 3 db

Event Recording Subsystem

To record the large number of event signals necessary to monitor the combined TRAP-1 system and sensors will require an even greater number of discrete event record channels since certain of the typical events relevant thereto will require multiple record tracks. For example, it is desirable to record gimbal limits, and one can accumulate a need for 36 record channels (2 per gimbal axis plus 2 for translation) for this purpose. It is anticipated that the total number of discrete event channels required will be between 125 and 150 by the time the upgraded TRAP-1 system is operational.

A 150-channel recorder has been selected for the upgraded TRAP-1 system. The selected unit is the Brush Operations Monitor. This type of unit has been used on another AERL program for approximately two years with quite reliable results.

The specifications for this unit are as follows:

Power Requirements:	150 VAC, 60 Hz, 150 watts nominal, 350 watts at maximum chart speed
Number of Channels:	150
Response:	Instant to 1.25 milliseconds at maximum chart speed
Chart Speeds:	5, 10, 20, 50, 100 and 200mm/sec plus 0.05, 0.1, 0.2, 0.5, 1, 2mm/sec with a divider switch in operation
Chart Format:	15 inches wide, 500 feet long
Temperature Range:	
Operating:	0°C to 55°C
Storage:	-40°C to 70°C
Weight:	124 pounds

Voice Recording Subsystem

A recorder for the specific purpose of recording voice from intercom systems on the aircraft will be the Ampex 602. AERL has used this type of recorder for the past five years and again plans to use this instrument in the upgraded TRAP-1 system.

Digital Subsystem

A digital subsystem is planned for inclusion on the TRAP-1 aircraft. This system will perform three major functions, those of data collection and storage, system testing and test data retrieval. The overall block diagram is shown in Figure I -39.

Data Collection and Storage

The primary function of the digital subsystem is to accomplish the on-line collection of data from both analog and digital sources and store the data in an efficient, easily recoverable form. In this mode, the digital system acquires data from external instruments, packs the data in the memory of the data processor, and records the packed data in computer compatible format on a digital magnetic tape. Prior to the actual collection of data, the operator

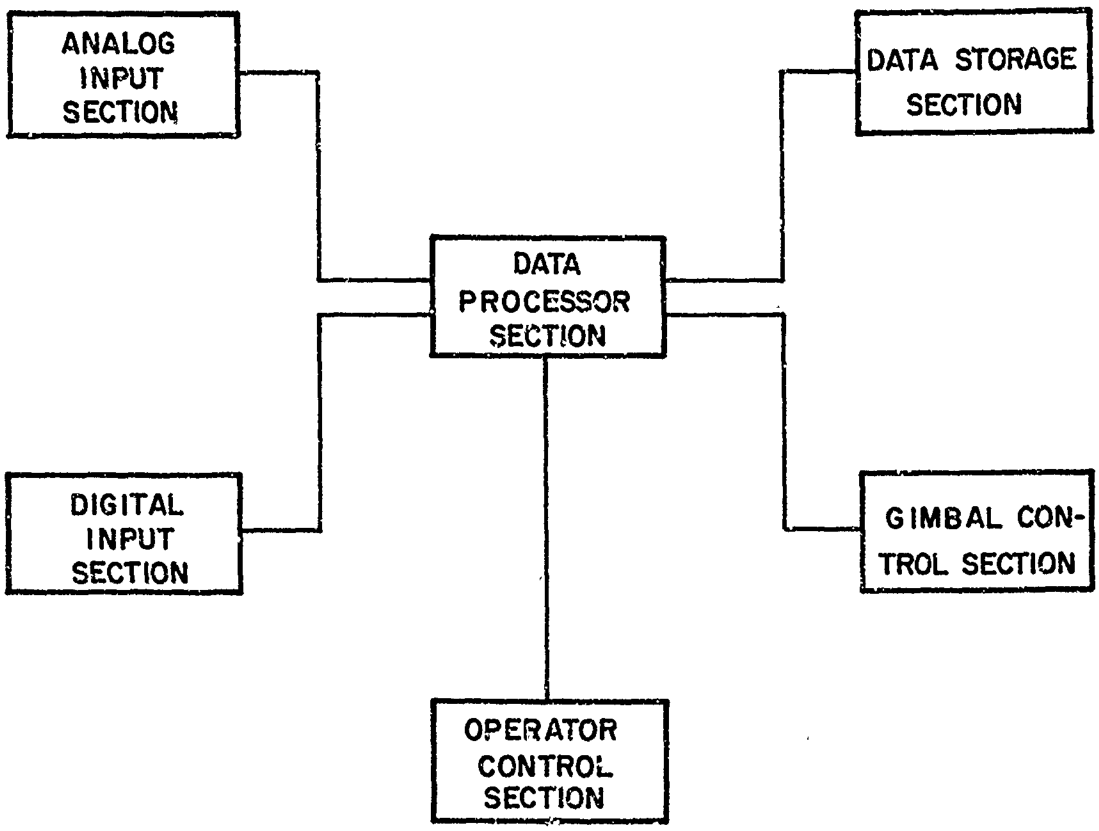

Fig. I-39 Major components block diagram, digital subsystem.

loads and initiates the proper program and enters setup information necessary to perform the function required for the specific test. The operator normally enters such information as scan rate, number of channels (analog and digital), scanning sequence (sub- and super-commutating permitted), etc.

When the operator has entered all required information, the system then runs through a final internal component check and awaits a signal to begin collecting data. Once data collection begins, the system assumes control of its own operation with the operator serving as an observer. When data collection ceases, the system returns to operator control.

The system will be capable of scanning at operator specified rates varying up to 25 thousand data samples per second (25 KHz) with continuous scanning, and up to 40 KHz with burst scanning.

System Testing

The digital subsystem will be capable of testing not only its own status but will be capable of exercising the gimbal system through programmed rates, velocities, etc. The gimbal control section of the subsystem includes the necessary equipment to drive the master pedestal which, in turn, points the slaved pedestals. Each pedestal, as noted previously, is to be equipped with shaft angle encoders which will provide the processor with pedestal angle through a digital input. Test procedures for the gimbal system include driving the system with known functions and a comparison with the resultant pedestal motions. From these tests, one will be able to obtain, in the field, pedestal diagnostic data which will permit rapid systems analysis, pre-mission testing and positive corrective maintenance.

To aid in maintaining the system and to increase reliability, extensive self-checking features will be available. The system will be able to test and calibrate any of its internal components and identify actual or potential malfunctions, listing the probable cause or causes whenever possible. The system will also provide automatic procedures to check and validate the instrumentation and gimbal control equipment. This automatic checkout will greatly reduce time consuming pre-test efforts and minimize downtime due to the early and accurate diagnosis of malfunctions.

Data Playback and Retrieval Mode

Previously recorded tapes may be played back and the data retrieved at any time the system is not being utilized for other purposes. The retrieval proceeds at maximum processor speed, with the time required determined by the complexity of the calculations and the quantity of output. Output is via perforated tape, magnetic tape, digital printer, keyboard printer, or visual display. Since the data processor is a high speed general purpose digital computer, complex processing can be accomplished in very little time, the main limiting factor being the speed of the output devices.

System Description

Figure I -40 shows the detailed components of the planned system. These functions are as follows:

Analog Input Section

The analog input section consists of an analog multiplexer and an analog-to-digital converter. The analog multiplexer connects the input of a desired data channel to the analog-to-digital converter which then converts the analog voltage to a proportional digital number for input to the data processor. The data processor provides control and timing signals to the analog multiplexing and the analog-to-digital converter, as well as providing the address of the channel to be selected and converted.

Analog Multiplexer - The analog multiplexer provides the capability for 48 (expandable to 96) distinct channels of high level ($\pm$ 5 volts DC) analog signals to be connected to the analog-to-digital converter. Upon receipt of the channel address and a start command from the data processor, the analog multiplexer selects the addressed channel and connects its output to the input of the analog-to-digital converter. In the system application, the analog multiplexer is used at a maximum rate of 40 KHz, although capable of operating at a 60 KHz rate.

Analog-to-Digital Converter (ADC) - When the analog multiplexer selects a channel, the analog-to-digital converter converts the voltage on its input to a proportional digital number. This digital number consists of a 12-bit binary word--11 data bits plus a sign bit, and is presented in parallel to the data processor section.

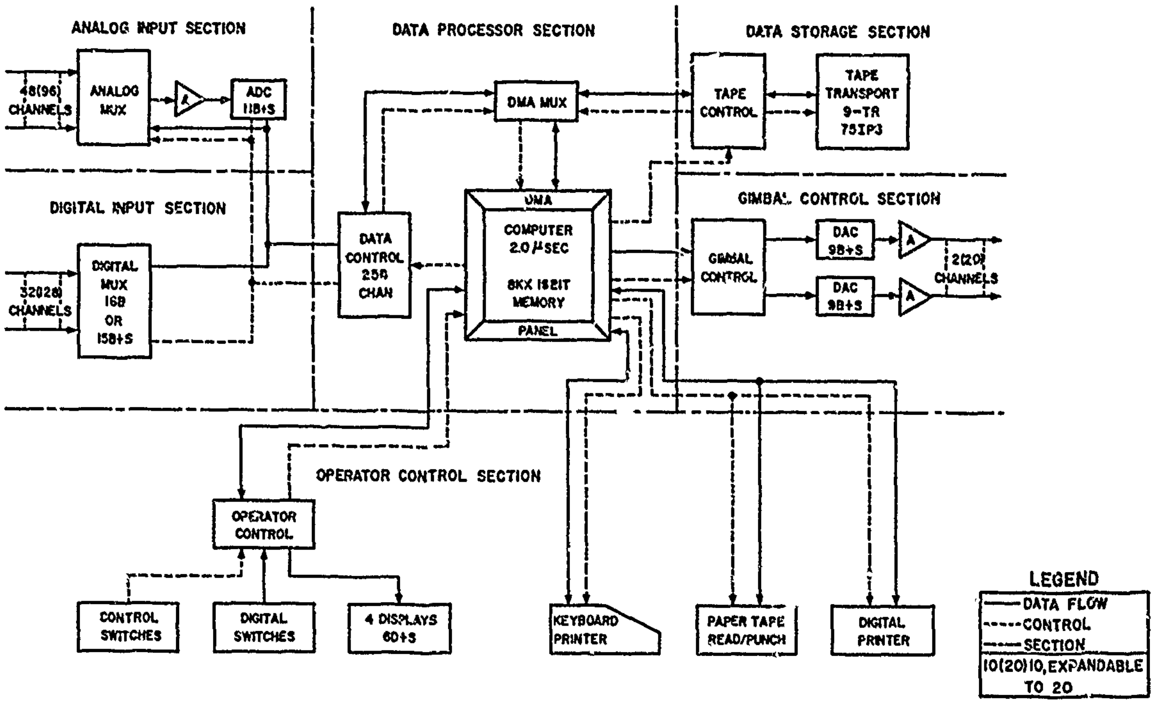

Fig. I-40 Digital data acquisition system, detailed block diagram.

Digital Input Section

The digital input section allows several digital inputs to be time multiplexed to the data processor. These inputs are presented as 16-bit parallel words.

Digital Multiplexer - The digital multiplexer is capable of multiplexing 32 (expandable to 128) channels of 16-bit digital information. After receiving an address and an initiate command from the data processor, a digital multiplexer connects the address channel input to a common output presented to the data processor and signals that the data is ready.

Gimbal position words (one word for each axis) from shaft angle encoders are presented in parallel to the digital multiplexer. Each word consists of a 16-bit binary data word (15 data bits plus sign). These words are presented in parallel and are the output of accumulators registering the current azimuth and elevation for each pedestal.

On/Off event signals are grouped into 16-bit words and presented in parallel to the digital multiplexer. On command, these words are selected and transferred in parallel to the data processor. Unused bits in any word are commonly filled with zeros.

Operator Control Section (Location)

The operator control section includes provisions for the operator to direct the progress of a test or checkout procedure and to monitor the results while the test is running. The operator control section also includes provisions for loading various programs into the memory of the data processor and for initiating these programs.

Operator Control Panel - The operator control panel contains the necessary displays and switches for convenient control of an operating program. Since the operator control panel is the main link between the operator and the system, its design is critical for effective system operation. For this reason, the operator control panel will be designed in conjunction with the detail design of the system. The operator control panel contains, as a minimum, push-button and decimal thumb wheel switches for entering control information into the data processor, status lights indicating the operational condition of the various system components, and illuminated displays for monitoring of the acquired data.

Ancillary equipment provided for input/output use will be a keyboard printer, a paper tape input/output unit for program entry and a printer for test and quick-look data presentation.

Data Processor Section

The data processor consists of a general purpose digital computer coupled with the necessary input/output interface to allow it to communicate with the other system components. The data processor exercises primary system control in all phases of operation.

Data Processor - The data processor is a standard general purpose digital computer consisting of a magnetic core memory and an arithmetic unit. The memory contains 8,192 memory words, each consisting of 16 binary bits of information. The memory has a complete read/write cycle time of 2.0 microseconds or less. The arithmetic unit has full general purpose computing capability and its speed is characterized by an add time of 4.0 microseconds or less. The processor exercises all arithmetic and control functions for the system. A control panel for the data processor is also provided which is used for maintenance and checkout purposes only.

Input/Output Interface - The data processor is provided with an input/output (I/O) interface to allow it to communicate efficiently with the other system components. This interface includes separate channels for each device to transfer data to or receive the data from the processor. In addition, a single direct memory access (DMA) channel is provided which allows an external device to transfer a word directly to or from the core memory of the data processor without program intervention.

Direct Memory Access Multiplexer - Since two devices in this system require direct memory access (the data control and the magnetic tape unit), they must time share the single existing direct memory access channel utilizing the DMA multiplexer. This allows each device to transfer words directly to or from the memory of the data processor without program intervention.

Data Control

The data control unit accomplishes a transfer of data between the digital and analog input sections and the data processor. To allow the high system scan rates that are desired, the data control unit operates using one of the direct memory access channels from the DMA multiplexer. The data control unit obtains the addresses of the desired channels from the memory of the processor, outputs the address to either the digital or analog input section as specified, receives the digital data from selected channel, and transfers the data directly to the memory of the processor.

Gimbal Control Section

The gimbal control section provides for the output of analog voltage signals to control direction of pointing of the various gimbals. The input to the gimbal control section is a digital word from the data processor. This digital word is converted to an analog voltage and output by the appropriate channel to the specified gimbal control servo circuit.

Data Storage Secti n

The data storage section consists of a digital magnetic tape transport and associated control electronics. Complete read/write capability is provided and the tapes produced by the system are standard computer compatible format. All tape recording is done in IBM 360 format with the necessary gaps and check characters automatically inserted. Error checking is performed on all read and write operations with erroneous results indicated as tape system malfunctions.

Tape control provides the necessary logic to direct the operation of the magnetic tape transport to produce computer compatible tape in the desired format. All check characters, gaps, etc., required for IBM tape compatibility are automatically generated and checked to verify data accuracy.

Timing and Sensor Control System

The timing and camera control units provide the fundamental means for correlating all re-entry data. These units provide coherent coded time signals and camera sequencing commands which are recorded and, consequently, permit comparison of all data to a time resolution limited only by the data sensor.

The block diagram is shown in Figure I -41. The basic timing reference is the airborne rubidium clock. Also shown is the WWV or range time receiver. This is used to periodically synchronize the airborne clock and, when transmission allows, also be recorded. The digital synchronometer and distribution amplifiers complete the basic timing reference system. The control function is shown as three blocks to identify the differences required by cine, framing, and ballistic cameras. The flow of information and control within these units can be seen readily as well as their relationship to ancillary and related equipment. The major items are discussed more in detail below.

Airborne Rubidium Clock

This unit is the primary input to system timing and data reliability. The unit will give a much closer time correlation, reliability and freedom from ground stations than before possible. The drift rate is such that a 1 msec accuracy is easily achievable. It is designed for portable use under environmental conditions comparable to our need. The desired freedom from ground stations is due to the occasional necessity to operate in locations where neither range time nor NBS transmissions are readily available and are also due to our poor experience in the reliability with which WWV, etc., can be received on the Ranges. The specifications for this unit are as follows:

Specifications

Physical

Front Panel Indicators:	24 Hour clock movement with stepping sweep second hand Time and Frequency error indicators Servo loop null meter Battery current meter
Front Panel Controls:	Power on-off switch Fast-slow battery charge switch Fine tuning control Crystal oscillator bias control Servo-loop switch Time error indicator Automatic sync. actuator

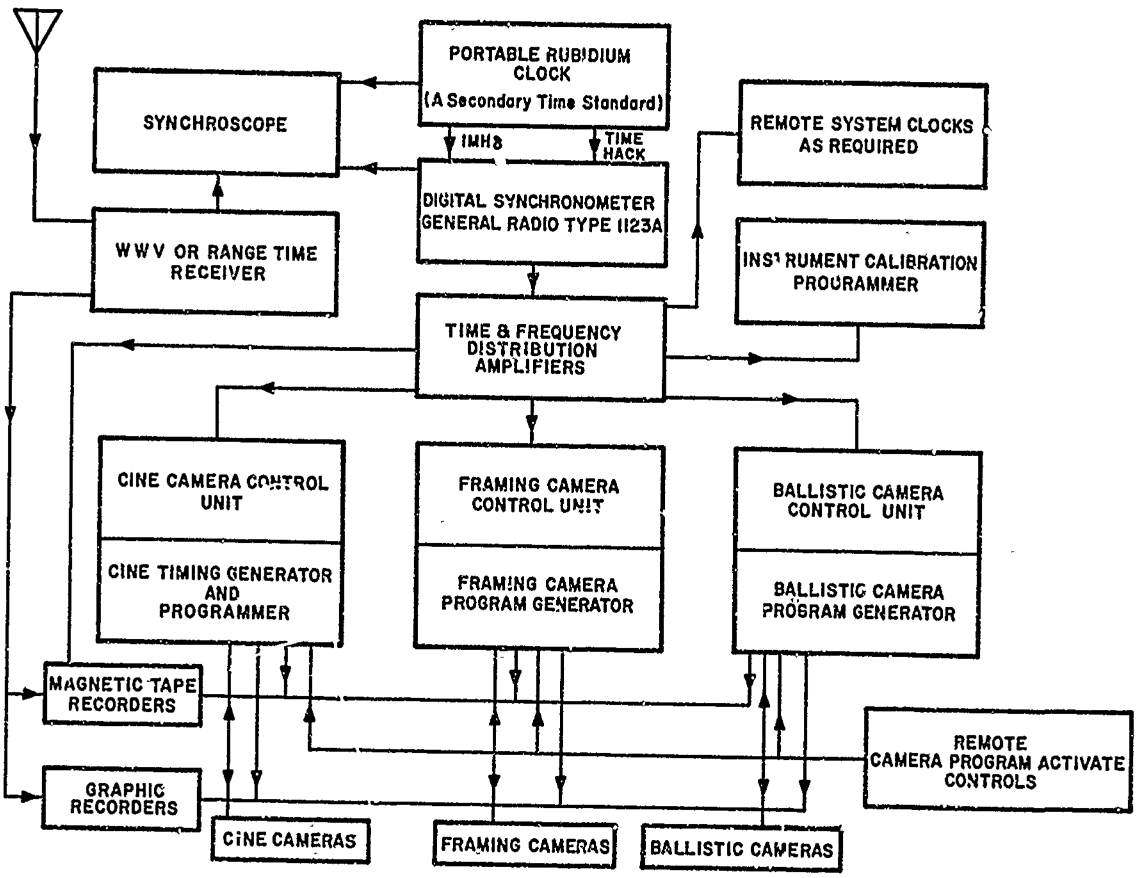

Fig. I-41 Timing and sensor control system block diagram.

R-6453

Electrical

Initial Frequency Setting:	$\pm 5 \times 10^{-11}$ relative to customer prescribed time scale
Accuracy:	After initial setting, accuracy is determined by the Long-Term Stability and Systematic Drift
Long-Term Stability:	5×10^{-11} (standard deviation) per year
Systematic Drift:	Less than 1×10^{-11} per month; 5×10^{-12} typical
Medium-Term Stability:	5×10^{-12} (standard deviation) for 100 second averaging
Short-Term Stability:	1×10^{-11} (standard deviation) for 1 second averaging
Tunability:	At least $\pm\ 1 \times 10^{-9}$ about the initial frequency setting; total range 4×10^{-9}

Digital Synchronometer

The digital synchronometer, General Radio Type 1123A, is a fully electronic modern method of precise local timekeeping when used in conjunction with a standard frequency oscillator. The device provides a means for comparing the local frequency standard against broadcast time signals in addition to providing several decimally related pulse rates and the time of day in parallel in binary coded decimal form.

Distribution Amplifiers

A distribution amplifier unit provides a low impedance coaxial line driving capability for the high impedance (100 kohm) time-of-day outputs of the General Radio Type 1123A synchronometer. This unit, in addition, provides the complements of these time-of-day signals and special once per minute and once per six-minute system synchronizing signals as well.

Synchroscope

The synchroscope chosen for the TRAP-1 timing system is a Tektronix Type RM561A with a Type 2A60 vertical amplifier unit and a Type 2B67 time base unit.

Its purpose is to permit comparison of time signals as received from WWV or range broadcasts with those of the on-board time standard and digital time distribution system.

Cine Camera Control Unit

The Cine Camera Control Unit (CCCU) is a switching and programming control for all cine cameras. Each camera of this type regardless of location in the TRAP-1 aircraft would be controlled, where functionally possible, from this central unit. Functions include camera on or off and in some instances slow or fast framing rate control. The basic method of set-up control for the CCCU is by means of a static punched card reader utilizing a standard IBM card. With the increase in control functions and operating flexibility necessitated by the TRAP-1 upgrading, individual switches become too numerous and a matrix approach is in order. The CCCU would provide up to twelve independent pre-set programs, one corresponding to each row in a standard IBM tabulator card, for each camera for each mission.

This pre-programming capability is a matrix outlined by the rows and columns of a tabulator card. Columns or groups of columns correspond to variables of a camera such as framing rate and timing lamp intensity and rows represent programming busses. Holes in the programming tab card at the intersections of variables and a buss cause cameras to operate in a mode determined by the chosen variables whenever that buss is activated.

A camera may operate at a slow rate when one buss is activated, not at all when another is powered and the same camera may frame at its fastest rate when yet another row (or buss) is activated. A complete absence of holes in the columns representing the variables of a particular camera at any row means the camera will be inoperative when that row is activated. A camera may be programmed to operate from any of the twelve busses and any of the busses may be activated or reactivated at will during a mission.

A static card reader and a programming tab card serve, then, as a crossbar switching complex to determine up to a dozen independent cine camera programs for each mission. The twelve programs will be remotely controllable and will facilitate the sequencing of cameras during the coverage of multiple vehicle re-entries.

The flexibility offered by this camera controlling system represents an operational capability an order of magnitude greater than presently available in any TRAP monitoring aircraft.

Framing and Ballistic Camera Control Units

The Framing and Ballistic Camera Control units are used to pre-set and functionally control all framing cameras and ballistic shutters.

Framing cameras require pulses of sufficient duration to initiate camera operation. The pulse repetition rate is that rate equal to the number of frames per second of data that is desired. Multiple choices of framing rates are required and are utilized for various types of sky background and re-entry configurations. Faster framing rates, with lower exposure times, in the case of a streak framing camera, are used on multiple object tests and with high sky background levels. Rates available must be from the highest speed desired (6 fps) to the lowest (4 seconds per frame).

Ballistic camera shutters are coded with the AERL main time format, pulse width code. This code permits unambiguous identification of the time sequence and time intervals. Two major options are available, with the shutter being open or closed for the binary "1" in the code.

In addition to the framing and shutter functions, the control units will provide precise voltages for proper exposure of fiducial markers on the film. These voltages are adjustable to optimize fiducial exposure to film type.

System trigger or turn-on functions are also controlled from these units, with the capability of sequentially initiating action on a pre-programmed basis. This technique has been in field use for several years, and is highly useful to sequence units for multiple re-entries and to assure proper time phased camera turn-on.

The assembler concept mentioned above in the cine section will be extended to these units. This will permit an unambiguous record of camera settings and prevent human errors in the operation of the system.

Re-entry Measurement Sensor Calibration

The function of a field calibrator is to maintain the precision of an instrument's calibration under data taking conditions. The primary characteristics desired in a field calibrator are: (a) calibration convenience, (b) stability, and (c) simplicity of operation. Implicit in (a) and (b) is the versatility of the calibrator, e.g., it is desirable to keep the source temperature constant and to vary apertures and/or filters, in order to obtain the calibration of an instrument from threshold to saturation. In addition, the

design of the field calibrator should be based on the criteria of simulation of the object-image relationship encountered downrange. This means simulating the illumination of the entrance aperture as well as the object-image dimensional relationship to the system resolution.

Experience with other TRAP aircraft clearly indicates the desirability of accomplishing calibrations from an on-board calibrator as the primary field type of calibration. Further, evaluation of the calibration unit presently in use on the TRAP-7 aircraft has shown it to have the characteristics described above, and it is anticipated that the design of the TRAP-1 calibrator will incorporate many of its features.

For an instrument which is inconvenient to remove from its gimbal because of weight, difficulty of realignment, the possibility of marring surfaces critical to alignment as well as the possibility of damage to the instrument itself, it is proposed that calibration external to the aircraft be considered. Consideration of the instrumentation on the TRAP-1 aircraft indicates that only the high resolution telescope (80" Jones Telescope) falls into this category.

Design Considerations

To determine the specifications which the TRAP-1 calibration unit must have, it is necessary to evaluate the characteristics of the data gathering instruments which are to be calibrated. For it to be suitable it must satisfy the simulation of object-image relationship in the field as described in the introduction. This means (a) the image, when unresolved downrange, must also be unresolved on the TRAP-1 calibrator: (b) the diameter of the collimated beam of the calibrator must be larger than the entrance aperture of the instruments to be calibrated for instruments which contain central obstruction; and (c) if the instrument does not contain a center obstruction, the diameter of the unobstructed portion of the calibrator should be larger than the entrance aperture of the instruments to be calibrated.

Table I -19 lists some of the important characteristics of the instrumentation on the TRAP-1 aircraft. The first 6 columns list some of the optical properties of the instrument. It should be noted in column 4 that for cameras the system resolution is determined by a combination of film and optics, while for radiometers it is determined by the reticle blade width. Column 6 indicates whether an obscuration is present in the instrument.

Adopting the criteria that an image is unresolved when its dimension is less than or equal to 1/3 the system's resolution and that it is resolved when its dimension is greater than or equal to 3 times the system's resolution, column 7 indicates, for a 100" focal length calibrator, the maximum aperture diameter allowed for simulating the object-image dimensional relationship to the system resolution. All instruments but two, namely, the high resolution telescope and the 40" cinespectrograph, do not resolve the image. Special attention must be given to these two instruments regarding the satisfaction of the simulation criteria.

Figure I -42 is a curve showing the image size variation with the slant range Z for a typical re-entry for the TRAP-1 aircraft for these two instruments. The image size on the Jones Telescope varies from 2.2 times the system resolution at acquisition to 3.3 times the system resolution at $Z_{min.}$. The image size on the 40" cinespectrograph varies from .67 times the system resolution at acquisition to the system resolution at $Z_{min.}$. This means that the image varies from partly resolved to resolved for the Jones Telescope and that it is partly resolved for the 40" cinespectrograph.

For these regions where the image is neither resolved nor unresolved, the simulation of the object-image dimensions relationship to the system resolution becomes more complicated. The requirement is that to produce simulation, the image size must approximate the dimensions obtained during re-entry. Thus, for these two instruments, column 7 of Table I - 19 shows two maximum aperture diameters, at acquisition and at the vertical point, respectively.

Columns 8 and 9 indicate the diameters of the calibrator beam which is required for calibrating instruments with and without obstruction. Thus, if the collimator beam has an obstruction of say 0.5", the beam diameter must be 13.5" to satisfy the object-image dimensional relationship for all instruments. While, if the collimator beam has no obstruction, the beam diameter must be 8.5".

Column 6 indicates the wavelength region over which the instrument is sensitive. The minimum wavelength is in the UV at a 3μ, and the maximun is in the IR at 3μ. It is clear that contemplated instruments will

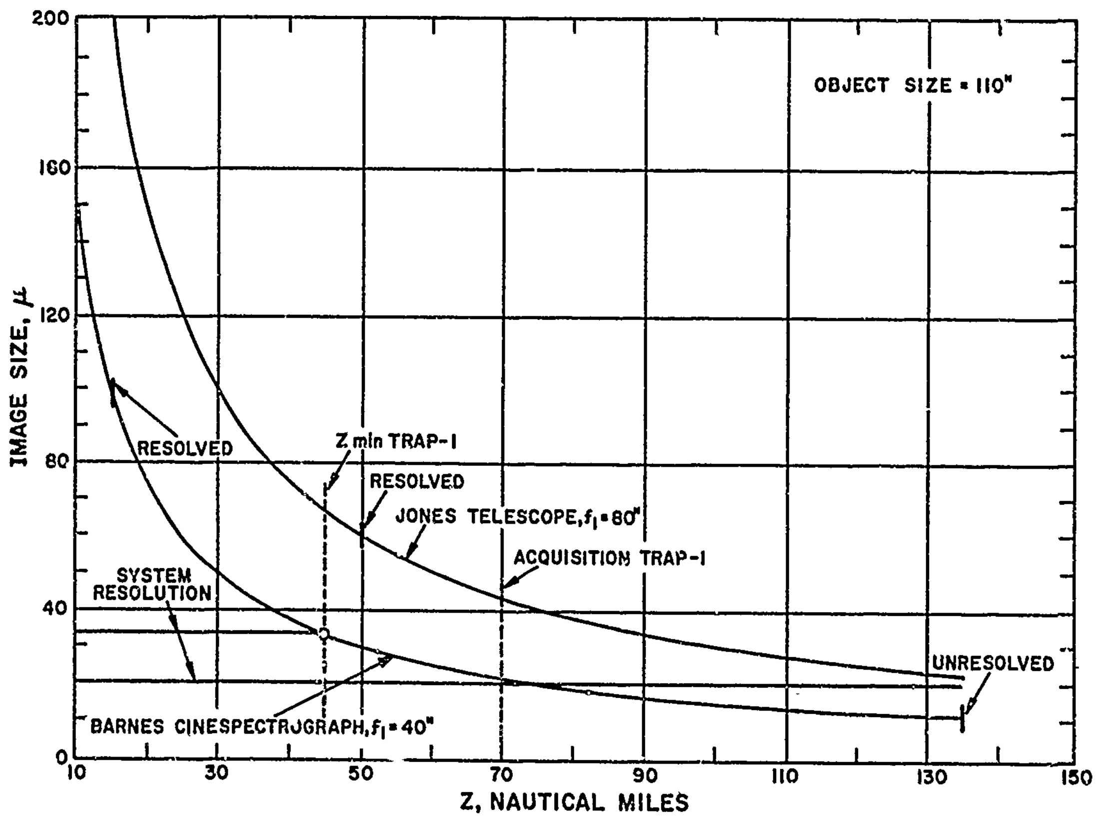

Fig. I-42 Image size variation vs. range for Barnes Cinespectrograph and Jones Telescope.

TABLE I-19

CONSIDERATIONS FOR CALIBRATOR FOR TRAP-I INSTRUMENTATION

INSTRUMENT	ENTRANCE APERTURE	FOCAL LENGTH	SYSTEM RESOLUTION	APPROXIMATE BAND PASS λ	OBSCURATION IN INSTRUMENT	MAXIMUM APERTURE REQUIRED FOR OBJECT IMAGE DIMENSIONS SIMULATION FOR 100" FOCAL LENGTH	COLLIMATED BEAM DIAMETER FOR INSTRUMENTS WITHOUT OBSTRUCTION	COLLIMATED BEAM DIAMETER FOR INSTRUMENTS WITH OBSTRUCTION
	INCHES	INCHES	MICRONS	MICRONS		INCHES	INCHES	INCHES
TWIN SUPER STAR	5	12	33-50	.4-.7	No	.0036	5.5	
HIGH RES. TELESCOPE	6	80	▲(43-66) 20	.4-.7	Yes	▲(.0021, .0032)		6.5
BARNES CINESPEC.	5	12	28-50	.3-.7	Yes	.0030		5.5
40" CINESPEC.	6	40	▲(22-33) 33	.4-.6	Yes	▲(.0022, .0033)		6.5
BARNES TRACKER	6.06 8.00	20 80	*5,842	.4-3.0	Yes	.39 .093		6.5 8.5
DUAL CHANNEL VS/IR RAD.	8	40	*254	.3-.7 1.3-3.0	Yes	.0086		8.5
A-LINE RAD.	7	17	*1,852	.5890±.0012	Yes	.14		7.5
12" VIS-IN-LINE CINESPEC.	6	12	33-50	.3-.7	No	.0036	6.5	
12" VIS-IN-LINE CINESPEC.	6	12	33-50	.6-.8	No	.0036	6.5	
UV STREAK SPEC.	2	4-5	33-40	.3-.7	No	.0088	2.5	
IR STREAK SPEC.	2.8	6-8	28-40	.5-1.0	No	.0043	3.3	
WILD "NODDING" BALL	1.5	6	33-50	.4-.7	No	.0075	2.0	
TWIN STREAK BALL	1.5	6	20-33	.4-.7	No	.0048	2.0	
VIS STREAK SPEC.	2.8	6-8	33-50	.4-.7	No	.0053	3.3	
16mm BORESIGHT CINE	2	3-6	20-33	.4-.7	No	.0048	2.0	
TWIN STREAK SPEC BALL	1.5	6	20-33	.4-.7	No	.0048	2.0	

* RETICLE BLADE WIDTH DETERMINES RESOLUTION

▲ SYSTEM RESOLVES AND/OR PARTLY RESOLVES. FOR SIMULATION APERTURE IMAGE <u>MUST EQUAL</u> QUANTITIES IN PARENTHESIS

probably extend further into the IR.

While it is true that the transmission of the quartz end window of the tungsten ribbon lamp extends to approximately 4.5μ (50% of peak transmission), the decrease as well as the uncertainty in the values of emissivity in the IR would indicate that both a tungsten ribbon lamp and a black body source are required for the TRAP-1 calibrator.

Photomultiplier Unit for the TRAP-1 Aircraft

The unit which will assure that the downrange calibrator itself remains in calibration is a photomultiplier or photodiode unit which has been calibrated in the AERL calibration laboratory. It is anticipated that the unit used in the TRAP-1 aircraft will be one manufactured by EG & G provided that the evaluation of the unit, which is now in progress, proves it to be sufficiently stable and ruggedly built with enough sensitivity for the TRAP-1 and Jones Telescope calibrators. The two photodetector units which are available have an S-20 and S-1 surface. The S-20 surface covers a wavelength region of approximately .350-.80μ while the S-1 surface extends this range into the IR to approximately 1.2μ.

This range does not include those wavelengths covered by a PbS detector. Two possibilities exist: (a) if the wavelength regions covered by the unit show that the calibrators are in calibration, extrapolation is made to the PbS region; and (b) provision of another head which contains a PbS detector. It would appear that (a) is sufficient and that extrapolation can be made confidently.

Calibration Philosophy

The field calibration scheme proposed for use on the TRAP-1 aircraft will satisfy the following: (a) All field calibrations will be performed with an on-board calibrator; (b) All instruments except the Jones telescope will be calibrated on the TRAP-1 calibrator and will be easily removable from their gimbals; (c) A photomultiplier or photodiode will be used on the TRAP-1 aircraft to assure that the calibrator remains in calibration; (d) The photomultiplier unit will provide wavelength coverage from .75μ to 1.2μ; (e) Extrapolation of the calibrator's performance into the IR will be made on the results obtained from the .35μ to 1.2μ response of the photomultiplier unit.

Requirements for the TRAP-1 Field Calibrator

Based on the data shown in Table I - 19, the initial specifications for the TRAP-1 calibrator can be determined. They are: (1) A collimator diameter of 13.5" if it is obstructed or 8.5" if it is not; (2) A collimator focal length of 100", (3) A complex of aperatures varying in diameter to a maximum of .009" and containing apertures with diameters of .0021" and .0033" to satisfy the simulation criteria for the 40" cinespectrograph; (4) A black body source and a tungsten lamp. A schematic of this preliminary design is shown in Figure I -43.

The following subjects must be considered before finalizing the design specifications for the upgraded TRAP-1 aircraft calibrator and its ancillary equipment: (a) Consideration of the combinations of calibrator source irradiance and the various apertures and filters for the purpose of determining whether they will provide each instrument with a calibration over the range from minimum detectable irradiance to saturation; (b) Evaluation of the EG & G photodetector units for the purpose of determining their acceptability as the secondary standard of the AERL calibration laboratory on-board the TRAP-1 aircraft; (c) Consideration of the problem of object-image simulation for systems like the 40" cinespectrograph where the image is not completely unresolved ($<1/3$ the system resolution).

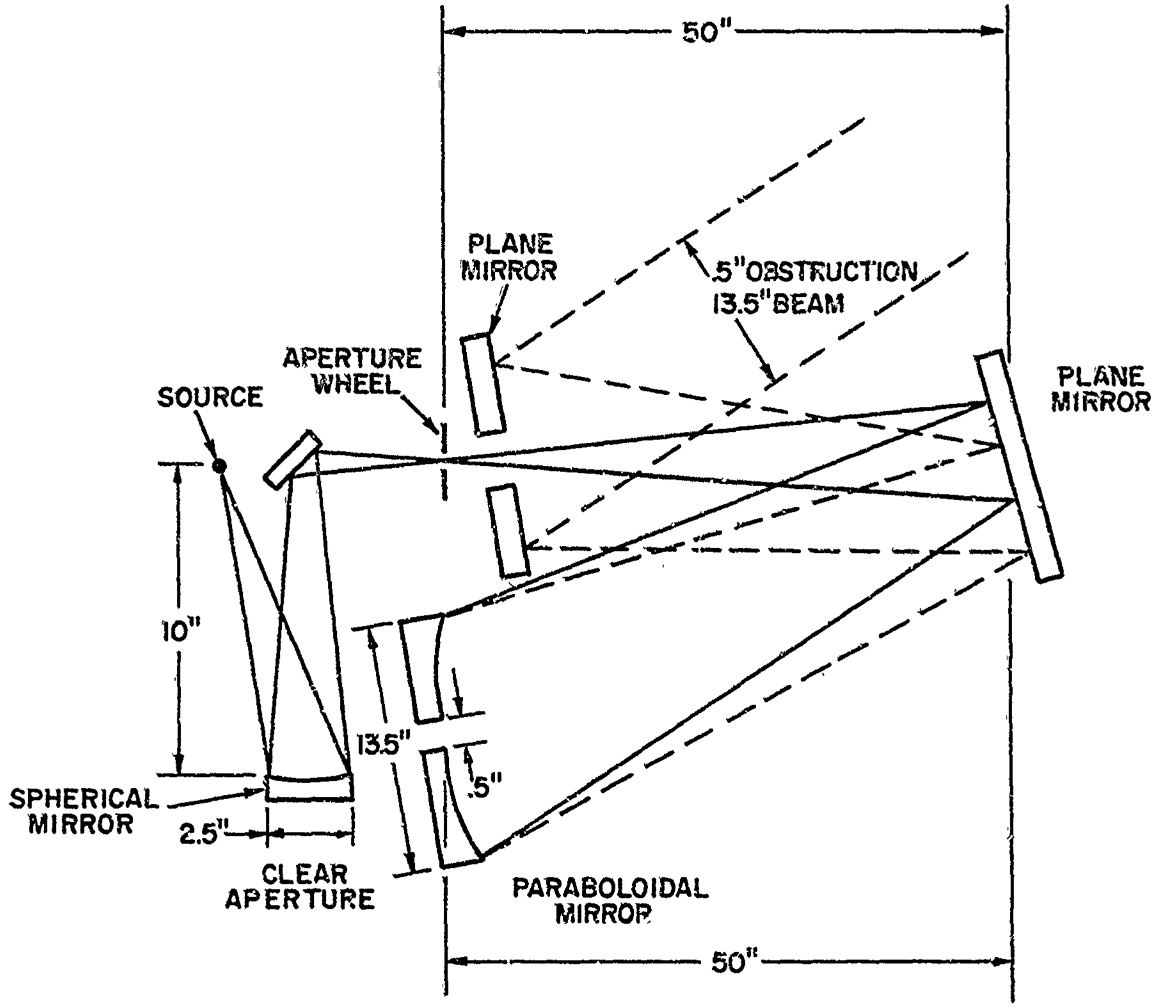

Fig. I-43 Schematic of TRAP-1 on-board calibrator.

CONTRACT F04694-67-C-0047

(TRAP-7)

UNCLASSIFIED TASKS

SECTION II

TASK 1.0 MANAGEMENT

R. M. Kadle

This semi-annual program progress report is the first such report issued by Avco Everett Research Laboratory under its new contract for the operation, data reduction, and reporting for the TRAP-7 KC-135 re-entry monitoring aircraft. The contract, F04694-67-C-0047, was issued by the Air Force Ballistic Systems Division, now part of the Space and Missile Systems Organization, and commenced on January 16, 1967 for the management portion, with the remainder of the contractual effort becoming effective on February 1, 1967. System Studies and Data Interpretation Studies are also included under the contract. Prior to February 1st, Aerojet-General Corporation was the agency which outfitted the TRAP-7 aircraft with the instrumentation system and operated the system during its checkout phases.

The reporting period covered is from February 1st through June 30th, 1967, with a few pertinent inputs from later points in time. The following discussion will dwell on the major aspects of management during this period and will summarize all tasks included in the contract.

The first important phase was preparation for and execution of the takeover of the TRAP-7 instrumentation system. The preparation commenced in the last half of January, while at the same time TRAP-7 was covering its last missions under Aerojet-General operation and returned to Wright-Patterson Air Force Base. On January 31st, an Avco Everett team arrived at Dayton to commence the takeover phase. For various reasons, there was no interface with Aerojet-General personnel. The first step executed was the inventory of the system on the aircraft. Immediately thereafter the team commenced a careful turn-on and evaluation of the system. The basic information available was that which was contained in the system manuals written by Aerojet. Gradually all portions of the system were actuated, followed by operation

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and checkout of individual instruments and subsystems.

Quite a few items required attention in the form of repair, maintenance, or adjustment, which were detailed in a report to Aerospace designated as TRAP Memorandum #1,"TRAP-7 Takeover Report." The takeover period reached an arbitrary conclusion in the middle of February when maintenance on the aircraft itself by Wright-Patterson personnel resulted in the aircraft being no longer available to the Avco Everett team. There was no opportunity for an actual flight test prior to takeoff for an ETR mission on the 24th of February.

The first mission was unsuccessful largely due to human error, and the third mission was conducted under daylight conditions on the WTR. All remaining missions (one at White Sands; six others on the WTR) were successfully covered, and a Re-entry Data Report was issued for the data obtained.

Items requiring maintenance were taken care of as time permitted. The maintenance of a complex instrumentation system which includes 10 gimbals requires considerably more attention than manual-tracking systems, but the time required for maintenance of the aircraft itself, such as 100-hour inspections and fuel leak repairs, and the time spent in flying between Dayton and the Pacific made it difficult to schedule and actually obtain sufficient access for instrumentation system maintenance. The first time period attained for a comprehensive system alignment was between May 27th to June 5th.

Significant attention has been directed towards the T-9 tracker and its acquisition capability. It employs a lead sulfide detector, which with its lesser sensitivity than photomultiplier trackers, means that there is less time available when the signal is great enough for an auto-track lock-on. Also, there are special techniques for target acquisition and adjustment for this tracker. Thus with respect to autotracking of targets, extensive autotrack was achieved on one mission in June (and another in July), with lesser amounts on several other missions. However, at all times the tracking operator stayed with the targets so that data continued to be obtained whether he or the T-9 tracker were pointing the gimbal system.

System documentation is a very important item, especially in the takeover of an instrumentation system which the laboratory did not fabricate. The system manuals available initially were helpful, but not complete for proper system maintenance. Much attention was devoted to obtaining full-scale drawings. The system drawings eventually were made available; however, these contain some inaccuracies, and considerable time was also spent in tracing the real-life situation with respect to system interconnections, location of power supplies, etc.

During the takeover phase, it was promptly noted by Avco Everett that it was possible for the downstairs gimbal system to shear the existing stops and strike the windows of the aircraft if gyro failure, although a low-probability occurrence, were to occur. This resulted in an immediate effort on the design and implementation of a set of much stronger gimbal stops for the 3- and 4-axis gimbals in the main cabin. By the end of the period the stops had been made and were awaiting an opportunity for installation. In the meantime, the aircraft operated at lower altitudes than usual and the personnel aboard were harnessed to minimize hazard in event of rapid decompression. The need for these gimbal stops resulted in the initiation of the first Contract Change Notice to Avco Everett's TRAP-7 contract.

Turning to the data aspects of the contract, data has been successfully and continuously obtained and reduced from all of TRAP-7's wide range of instrumentation except the R-51 radiometer, whose gimbal requires the most sensitive alignment. Among the best instruments aboard from the standpoint of data have been the Barnes cinespectrographs whose excellent sensitivity and spectral resolution have provided important additional spectra on R/V's and emanations which heretofore have not been detected. The techniques for data reduction for all TRAP-7 instruments already existed at Avco Everett, and the processing of TRAP-7 data loads commenced immediately and effectively. The highlights for each type of data collected are summarized under Task 3, and the TRAP-7 Re-entry Data Reports issued for missions covered for the reporting period are listed and abstracted under Task 7. In summary, the employment of

TRAP-7 by Avco Everett Research Laboratory was promptly successful from both the operations and data viewpoints.

Calibration is of course the basis for deriving valid data. For this contract calibration is a separate task (Task 5), and this subject received prompt and thorough attention during the reporting period. The Aerojet J216 calibration unit is an on-board system on which instruments in the main cabin can be calibrated immediately following a mission. The J216 calibration unit was thoroughly evaluated, and a comprehensive report is given under Task 5 in this progress report. In general, the unit was found to be usable from both the operation and data viewpoints; however, it was found that irregularities in the attenuating filters used in the system combined with their location in the unit's beam produced some results different from those which had been previously documented.

At this point it is appropriate to discuss the aspect of discrepancies with previously documented information which may be noted in various portions throughout this progress report. Whether the discrepancies or corrective actions employed pertain to calibration information, system condition or alignment, or instrument capability, they are documented not with the intent to be derogatory but because of the necessity for Avco Everett to establish the actual capability of a system and veracity of the re-entry data obtained. Whenever a discrepancy was found or a correction required, we proceeded to ascertain the cause of the problem and to take constructive steps wherever possible within the scope of the contract.

With respect to studies, there are two categories incorporated into the present contract: system studies and data interpretation studies. Within system studies, there are two types of efforts. The first pertains to modification of R/V's to enhance optical acquisition and data interpretation; because of a closely related study issued under the -865 contract, we requested that realignment of this effort concentrating on a special mission to be flown this fall. This study is discussed in the classified volume under Subtask 4.1. The other system study effort pertains to system upgrading, and a summary discussion of this subject can be found under Subtask 4.2 in the unclassified volume.

The basic intent of the data interpretation study is to provide R/V diagnositcs based on the data collected by TRAP-7. Obviously, with Avco Everett's operation of TRAP-7 having just commenced, there is not a great backlog of data to be analyzed. However, there have been some very interesting results obtained during these first nine missions. Some of these analyses, e.g. on body dynamics, were incorporated into one study to provide a cohesive discussion of the subject. In this case the study was issued under the -865 contract (Subtask 2.1.2) but incorporates TRAP-7 data and analysis thereof. In another case, TRAP-7 collected some unique spectra and the analysis of this data is discussed under the TRAP-7 contract (Task 6). An examination of TRAP-7 data from the standpoint of R/V survival is also discussed under Task 6.

Re-entry Data Reports for each mission are listed and abstracted under Task 7. These are to be issued seven weeks after receipt of data at the laboratory; however, the contractual data load level is two loads a month, so that when missions bunch in occurrence there must necessarily be some delays in issuing the reports on these missions. Reports for all seven missions where extensive data was collected have been published and distributed, and letter reports sent to SAMSO and Aerospace on the two other missions.

A new type of report was instituted during the period, termed TRAP Memoranda for the purpose of reporting promptly to SAMSO and Aerospace on topics which had been requested and/or pertain to subjects which would not necessarily receive wide distribution. TRAP Memoranda were issued for both the -865 and -0047 (TRAP-7) contracts, and those issued for TRAP-7 are given under Task 7. These reports are not available to the community at large, although in some cases portions of the information are being published in progress reports such as this, or in research notes.

TASK 2.0 OPERATIONS AND MEASUREMENT

R. S. Warner

For the -0047 contract (TRAP-7), Task 2.0 encompasses both field operations and system maintenance and repair.

Field Mission Coverage and Aircraft Activity

During the period from 1 February to 30 June 1967, the TRAP-7 KC-135 aircraft participated in nine re-entry monitoring missions plus an additional mission resulting in no target. (A mission is defined as an activity for which the aircraft was on station and the missile was launched. Therefore, both successful and unsuccessful missile flights are included; last minute test postponements, even though TRAP-7 was on station, are not included.) A summary of TRAP-7 aircraft activity is given in Table II-I.

The first weeks in February were devoted to the operational takeover of the TRAP-7 system under the new AERL contract. Details of checkouts, repairs, and adjustments of the TRAP-7 equipment during this period are included in the TRAP-7 Takeover Report (TRAP Memorandum #1) and are summarized in the next section. Aircraft availability during the first part of this period was somewhat limited but in general allowed an eight to twelve-hour working day. Due to aircraft maintenance and fuel leak work starting approximately 18 February, several items which were planned to be accomplished before the first re-entry mission could not be done. These included running practice missions and tracking targets from the ground for dynamic pointing evaluation and complete airborne system checkouts and tracking.

The TRAP-7 system covered its first mission under the AERL contract on February 25 at Ascension Island. Because of the aircraft maintenance and fuel leak work, TRAP-7 did not leave Wright-Patterson AFB until approximately 15 hours before re-entry time; thus, after the flight from WPAFB to Ramey AFB in Puerto Rico and refueling, the mission was staged from Ramey.

As shown in Table II-I, TRAP-7 has been active during the reporting period; not shown on this table are the many times that tests were scrubbed

TABLE II-1

ACTIVITY LOG FOR TRAP-7 AIRCRAFT

TABLE II-1

MONTH OF February

Start AERL system takeover at WPAFB

Takeover work aboard A/C suspended because of A/C maintenance and fuel leak work

Depart for Ascension for ETR 2975, via Ramey AFB

ETR 2975; minimal data obtained (stage from Ramey AFB, recover Ascension)

Return to WPAFB via Ramey AFB - fuel leak repairs scheduled

MONTH OF March

WSMR 66; data obtained (stage and recover WPAFB); 2nd test scrubbed

Depart for Norton AFB from WPAFB

Depart for Honolulu from Norton AFB for test WTR 9035

Fly for WTR 9035 - scrubbed

WTR 9035 (daylight), moderate data obtained (stage and recover Honolulu)

Fly for WTR 7941 - A/C left station because of low fuel (stage from Honolulu, recover Wake)

Wake Island to Honolulu

Return to WPAFB

A/C flown for ASD tests

A/C in for 100-hr. inspection and fuel leak work

MONTH OF April

Depart for Honolulu from WPAFB for WTR 2997

Fly for WTR 2997 - Test scrubbed

Fly for WTR 2997 - Test scrubbed

WTR 2997; data obtained (stage from Honolulu, recover Wake) Return from Wake to Honolulu

Fly for WTR 7995; No target no data (stage and recover Honolulu)

Depart Honolulu for WPAFB

Depart WPAFB for Honolulu, via March AFB

WTR 3339; data obtained (stage and recover Honolulu)

Depart Honolulu for WPAFB

(A/C 100 hr inspection)

TABLE II-1 (Cont.)

MONTH OF May

Depart WPAFB for Honolulu for WTR 7217, 1601 and 3282

WTR 7217; data obtained (stage from Honolulu, recover Wake)

Depart Wake for Honolulu

WTR 1601, data obtained (stage from Honolulu, recover Wake, refuel and on to Guam)

WTR 3282; data obtained (stage from Guam, recover Wake, refuel and return to Honolulu)

Depart Honolulu for WPAFB

(Aircraft Available for AERL System Maintenance)

MONTH OF June

Depart WPAFB for Honolulu

WTR 2766; data obtained (stage from Honolulu, recover Wake, refuel and return to Honolulu)

Depart Honolulu for WPAFB

(A/C 100-hr. inspection)

MONTH OF ______

shortly before takeoff and the premission checkouts on the system were underway. Several "doubleheaders" were scheduled; on these TRAP-7 covered one at most because of fuel shortage, test cancellations, or missile difficulties. This type of operation on the Western Test Range entails staging from and recovering at Wake Island to give the longest possible on-station time. The ferry flight to Wake from Honolulu often has to be arranged for arrival many hours before a scheduled departure for the mission, because of the limited servicing facilities at Wake.

The aircraft monitoring activity, along with aircraft maintenance and fuel leak work when TRAP-7 is at WPAFB, has reduced the amount of time available for required system adjustment and alignment. Future operation of the TRAP-7 system must provide for sufficient time when the aircraft is totally available for systems work as required.

Extensive data was collected on seven of the nine re-entry missions, with the first (human error) and the third (daylight conditions) being the exceptions. The types of targets ranged from experimental through operational vehicles. Locations of monitoring included one mission on the ETR, one at WSMR, and the remainder on the WTR.

Summary of Takeover Effort

The operational takeover by AERL of the TRAP-7 re-entry monitoring system began at Dayton with the start of the contract on 1 February. Prior to this time two weeks of planning effort had resulted in a plan-of-attack and a schedule of milestones. The schedule was based on working two shifts per day for two weeks, and the proper arrangements were made with ASD at WPAFB for the support required. The TRAP-7 system was divided into several subsystems for the purpose of learning, testing, and making operational checkouts. A lead person and support team were assigned for each area. As manuals on the system arrived from Aerospace, they were copied and distributed to the personnel involved in each task. Several meetings were held in which each group leader presented the system information in his area to the rest of the takeover team, and discussions were held concerning the plans of each group and the interface and coordination of the work. The personnel level at Dayton during the takeover period ranged up to 19 persons for the first two weeks of February.

Consumable items such as film, magnetic tape, chart paper and other expendables were procured and shipped to Dayton during the last week in January and first week in February. Test equipment needed for the takeover period and for operation of the TRAP-7 system was shipped to Dayton in the first few days of February.

Preliminary operational procedures and documentation were prepared prior to 1 February and continually updated during our familiarization with the system. Much of this documentation was derived from the Aerojet systems manuals, with some modifications made on the basis of our experience with similar systems. Arrival of the takeover crew at Dayton started on 31 January. After the first few days of working on the aircraft at Dayton it became apparent that a one-shift, twelve-hour day was preferable to a two-shift day. This was possible because there was minimum interference between the various groups, and the original plan of limiting the number of persons on the plane to approximately six (and the number of separate tasks to two) was not necessary.

The first two days of the takeover period were taken up with inventory of the TRAP-7 system aboard the aircraft and with associated equipment located in Building 67 at WPAFB. All of the inventory lists available at this time were signed by the afternoon on February 2nd, and the system turn-on commenced immediately.

<u>System Turn-on</u>

System familiarization and turn-on encompassed approximately two and a half days. At the end of this time, several persons were checked out on the system and we were ready to proceed into specific instrument and subsystems testing. The camera control system and the J216 calibration unit were among the first subsystems undertaken and, concurrently with continuing system "turn-on," the camera checkouts and calibration evaluation began.

Cameras, Mechanical and Optical Systems

A thorough checkout was made on each camera in accordance with a checklist which was accomplished for each instrument where applicable. The first cameras to be checked were those which were to be used for the initial evaluation of the J216 calibration unit; these were the Wide Angle camera (35 mm Giannini 207), the High Speed DBM V, and the Sodium D (DBM 4M1) cameras. As these were checked and any discrepancies corrected, they were calibrated on the J216 and the films returned to the laboratory for processing and evaluation.

Several TRAP-7 cameras and a DBM V from the laboratory were calibrated both on the J216 calibrator and on the AERL in-lab facility.

A photomultiplier was also calibrated on the AERL facility and on the J216 unit (two days of measurements). (An evaluation of the J216 unit is reported under Task 5.0 of this semi-annual progress report.)

Time, Control and Recording Systems

This area encompassed operational checkouts and calibrations of the systems listed below.

- Power distribution
- Timing
- Camera Control
- Recorders, tape and chart
- Interphone
- Calibration unit (electrical check)
- Test equipment

Lack of documentation was a major delay factor in the tracing of power and signal distribution throughout the system.

Radiometers, Tracker, and Video Systems

The radiometers and tracker were tested for: electronics calibrations; transfer characteristics from preamp input to recorder input; dynamic range and gain; and absolute intensity calibrations.

Preliminary checks of R-71 and R-51 radiometers indicated that both instruments were in working order. The T-9 tracker was used to track slow moving targets and behaved normally. Both the Image Orthicon and Vidicon were operational, although difficulty was encountered in turning on the Vidicon due to a hidden undocumented power supply.

Tape recorders were operated and calibrated. Both radiometers and the T-9 tracker were calibrated. The R-51 and T-9 were calibrated using the 27-1/2 ft collimating lens and a 1000° black body from Avco's laboratory, and the R-71 using the J216 calibration unit. The tapes were returned to data reduction at the laboratory.

Gimbal System

On initial turn-on, the gimbal system (except for the 4-axis) operated in a gross sense, that is, all gimbals moved in both of the rotational axes and in translation. However, each gimbal followed commands differently, some greatly overdamped and others overshooting. Each of the axes of the three-axis and the two-axis gimbals were adjusted according to procedures outlined in the AGC manuals. When the entire system was run, several malfunctions and problems were noted.

Primarily, the 400 cps reference supply would trip to line power, causing the system to shut down for about a minute, after the system had been on for ~ 10 minutes. Isolation of this problem was traced to the horizontal translational axis of the 4-axis gimbal. At this time it was decided to concentrate on the rest of the system and get that operating properly before attacking the 4-axis gimbal.

Another problem became evident while attempting to adjust the rest of the system which was eventually traced to noise spikes coming from the reference supply. When this problem was traced to the reference supply, it was decided to run the gimbal system on aircraft line power until there was a resolution of the reference supply malfunction.

Mechanical checks were made of all gimbals. The most prevalent problem rust on the clutches of the horizontal drive motors (translation axis); these had to be disassembled, cleaned, lubricated, and reassembled. All gimbals were electrically actuated and the checks as outlined in the manuals were made. Adjustments, repairs or replacements included damping, integrator amplifiers, isolation amplifier converters, and power amplifiers. Axes of all gimbals were adjusted according to the AGC manuals.

Operational Procedures Training

Upon completion of system familiarization and systems engineering tasks (during which the operations crew worked closely with the laboratory engineering personnel) the system was turned over to the operations crew. The operations training actually started prior to completion of troubleshooting of the gimbal system because of time limitations and because this parallel effort could be accomplished with little interference.

Check lists, which had been constantly updated during the takeover period, were run through by the crew, and premission, mission, and postmission procedures practiced. This included boresighting and alignment, electronic calibrations, and other setup and checkout items. On the evening of 13 February a complete system ground test was run in the form of a simulated mission. "Data" from this test were immediately forwarded to the laboratory for processing, evaluation, and feedback of information to Dayton.

The next few days were spent performing cleanup of tasks previously left incomplete, of minor malfunctions occurring during the test, and again running through the mission procedures.

Preparations were made for a flight test on several occasions, but due to the unavailability of the aircraft, there was no flight test made before the first mission.

The "takeover" phase of TRAP-7 was essentially completed on 17 February, at which time the scheduled fuel leak work on the aircraft (during which no contracto personnel are allowed on the aircraft) prevented any further work.

Chronological Summary

A chronological summary of the takeover effort is given below.

			Aircraft Location H = Hangar R = Ramp
February	1	A/C Inventory	H
	2	A/C and Building 67 inventory complete 1530 hrs. - start turn-on at 1600 hrs.	H
	3	System turn-on (high res. removed to bench in Building 67)	H
	4	System turn-on - calibrator evaluation - cameras	H
	5	System turn-on - calibrator evaluation - cameras	H
	6	System turn-on (complete) - cameras - radiometers - calibrator evaluation measurements (complete)	H 2100 hrs.
	7	Radiometers - cameras - tracker - gimbals	R
	8	Radiometers - Vidicon - Orthicon - tracker - gimbals - cameras (complete)	R
	9	Radiometer and tracker (complete) - gimbals	H 2230 hrs.
	10	Gimbals - operations training	R (AERL on A/C 1300 hrs.)
	11	Gimbals - operations training (Electronics calibration)	R
	12	Gimbals - operations training (boresight and calibrations)	R
	13	Operations training - individual checklists run through - full-scale ground test (including complete calibration)	R
	14	Cleanup work - gimbals - operational procedure review (flight test scheduled)	R

February	15	Cleanup work - operations training - gimbals (flight test scheduled)	R
	16	Ground test lab feedback - adjustments and repairs made as required - operations training - gimbals (flight test scheduled if WSMR cancelled)	R
	17	ASD schedule announced: fuel leak work to start 2/18, to last ~2 days. (From this date on, flight tests were scheduled to be held as soon as the aircraft was available.)	R
	18	Part of AERL crew to Lab (3 persons left in Dayton).	H
	19	Sunday	
	20	Gimbal measurements relative to hitting windows - fuel leak work started	H
	21	Fuel leak and maintenance	H
	22	Fuel leak and maintenance (100 hr. run-up); AERL crew return to Dayton	H
	23	Fuel leak and maintenance	H
	24	0530 hrs. - takeoff for Ramey, test, Ascension (ETR)	

Notes

1) Aircraft undergoing maintenance until just prior to departure for ETR test.
2) During fuel leak work, no contractors were allowed on the aircraft.
3) Flight test cancellations were due to aircraft maintenance not being completed.

System Performance and Maintenance

The following sections summarize important aspects of system performance and maintenance occurring over the reporting period.

Pointing System

During the takeover period in February it was noted that there were

several discrepancies in the operation of the pointing system (see discussion above). Due to the limited time and availability of the aircraft at the end of February prior to the first mission, a complete system realignment was not performed. For several weeks attempts were made to adjust the pointing system in the field, but due to the nature and extent of the misadjustments, it was determined that a complete system readjustment was required. A request was made for aircraft availability for the necessary time to complete these tests, but because of the monitoring schedule and aircraft maintenance work, this time did not become available until the end of May. Efforts continued in the field to make system readjustments and significant progress was made. At the completion of the scheduled pointing system readjustment in May and June, the entire system was operating within test procedure specifications.

Some of the more significant items pertaining to the pointing system are discussed below:

400 Hz Reference Supply

During the takeover period when the system was first energized, the Reference Supply circuit breaker would trip after several minutes of operation. Because of limited testing time prior to the first mission it was decided to run the system on "filtered line." A spare static inverter was rewired and installed in the reference supply unit; this also resulted in the circuit breaker tripping although fewer noise spikes were evident. Further investigation after this revealed that the circuit breaker installed in this circuit was not rated properly and was tripping on the normal current drawn by the system. It was subsequently learned that this unit had not been used previously as an operating part of the pointing system. When using aircraft line power, the system did not operate properly on several occasions when faulty ground power units were supplying aircraft power. The reference supply and associated circuits have now been modified and the unit is used in the system.

Power Amplifiers

The power amplifiers for the gimbals are modified Westamp Model A466. Some of the spare units which came with the system were not modified and could not be used in the system in this unmodified condition. A study was performed along with contacts with the gimbal system manufacturer (Aerojet) and the amplifier manufacturer (Westamp) to determine modifications, specifications, and reasons for the modifications. Several amplifiers will be sent to the manufacturer for modification and upgrading to provide greater reliability and better system performance. Several problems encountered with gimbal adjustments are possibly attributable to the power amplifiers.

Buffer Amplifiers

Boresight shifting caused by the buffer amplifier has been noted. (Shifts can be seen as the buffer amplifier is tapped with a finger.) An investigation is now underway to eliminate this problem. Several of the amplifiers were not balanced when checked, and two could not be adjusted to balance; these were all adjusted or repaired as required.

Dynamic Slaving

All gimbals required considerable adjustment to be brought within system specifications; in several cases the rate loops could not be adjusted with the potentiometer provided for this purpose, and fixed resistors had to be replaced in the summing amplifier before adjustment could be performed.

Crosstalk in the elevation axis of several gimbals, when the gimbal rotated in azimuth, was corrected by mechanical rotation of the gyros.

Figure II-I shows the readout of the T-9 tracker boresight camera for a recent test, WTR 0510, in both azimuth and elevation. Twenty seconds of autotrack on the re-entry vehicle were achieved on this test. Readouts of the slave gimbals on this mission show generally good results and are now being analyzed.

Translation Axis

The translation axis motors/clutch assemblies have been

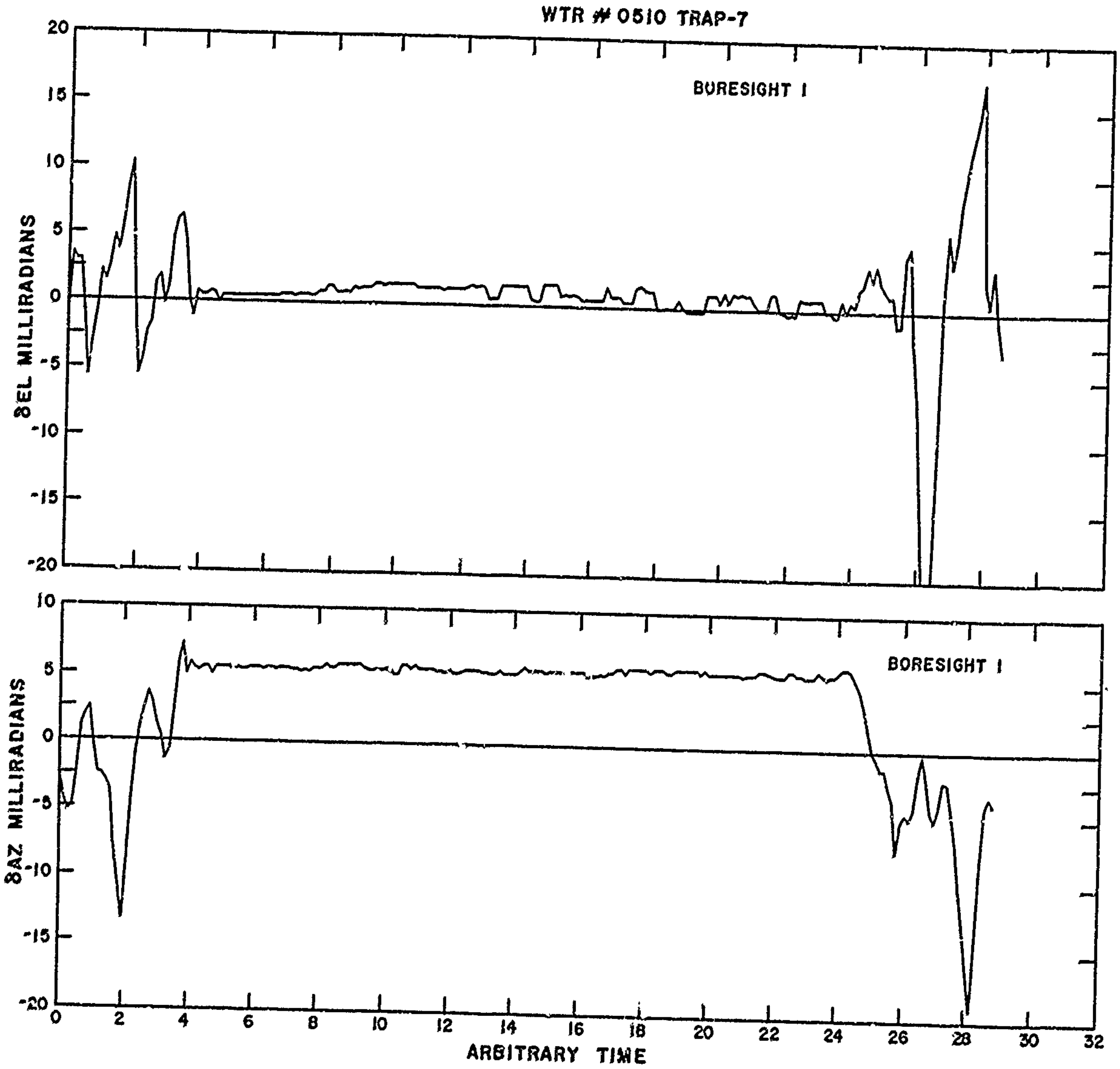


Fig. II-1 Target position readouts from the field of view of the boresight camera mounted with the T-9 tracker for WTR #0510. The autotrack lock-on portion extends from ~ 4 seconds to ~ 24 seconds on the abritrary time scale. Note that the elevation and azimuth scales are in milliradians, not degrees.

cleaned and readjusted, an alignment jig made and a torque setting procedure established to assure reliable operation. One of these motors (at Station 560) sheared a shaft during operation and a subsequent study resulted in the adjustment procedures.

Radiometer and Video Systems

R-51 Radiometer

Detector #1 in the R-51 operated intermittently on several occasions and the trouble was traced to a broken detector lead. Because of the construction of the detector/cooler/field lens assembly, the repair will be accomplished by the manufacturer (Aerojet).

Image Orthicon

A Bendix representative was contracted to perform repair and overhaul of the BX-8 Image Orthicon system at Dayton.

The major repair consisted of the replacement of a transistor in the input circuit of the video preamp in the BX-8 camera. This component was noted by the Bendix representative as being a high failure item in the BX-8 I. O. systems.

The system could not operate in the "line-lock" configuration since a unijunction transistor was missing. This component was replaced and the system completely realigned.

The photocathode of the I. O. tube which was in the camera was burned in several places, probably due to the operational mode employed with the system over a long period, i.e., pointing at a bright boresight target and "burning-in" the point image on the tube. The burning of the tube had deteriorated its sensitivity, and apparently neutral density filters had been replaced with less dense filters to compensate. Recommendations were made for proper filtering for use with a new I. O. tube.

Other recommendations were made by the Bendix representative regarding changes in the circuitry and an Image Orthicon tube which is very "burn" resistant; these will be further evaluated and incorporated into the system where practical.

Support System

The WWV receiver which came with the TRAP-7 system did not have

the capability of receiving range time (4.815 mc and 7.355 mc) and did not receive WWV well on the first few missions. The receiver which was formerly on TRAP-1 was borrowed and installed in TRAP-7 to provide better timing reception. This unit has been modified by AERL and has the range time capability.

Timing lamps in the Barnes cinespectrographs were changed from argon to neon to provide greater reliability.

Mechanical/Optical Systems

The cameras underwent complete overhauls and repairs during the takeover period and in general have provided good performance. The High Resolution camera was returned to the laboratory for a complete checkout and evaluation in February and a summary is included in this report.

The Sodium D camera has frequently produced distorted images in the data and is being evaluated to isolate the cause of image distortion.

J216 Calibration Unit

The filters were removed from the calibration unit in June and returned to this Laboratory for inspection (cf. Task 5.0). They were reinstalled and calibrations show no system change due to their replacement.

The TRAP-7 Instrument Table is given in Table II-2.

TRAP-7 Preventive Maintenance Program

The Preventive Maintenance Program was developed during the period to insure system performance. Maintenance schedules have been formulated for each subsystem element, and procedures established for feedback of reduced data on past performance. Schedules and records of system work are being maintained both at the aircraft and in the laboratory. Extensive maintenance manuals have been prepared for each of the four subsystems which comprise the TRAP-7 system.

The following sections summarize the major aspects of the program.

Objectives

Objectives of the Preventive Maintenance Program for TRAP-7 are:

a. To keep all components and subsystems of the TRAP-7 re-entry monitoring system operating at a specified performance level.

TABLE II-2
TRAP-7 KC-135 INSTRUMENT TABLE AS OF 30
AVCO EVERETT RESEARCH LABORATOR

INSTRUMENT	STATION, WINDOW MATERIAL	SPECIAL PROVISIONS	COLLECTOR FOCAL LENGTH & f/#	FIELD OF VIEW	SAMPLING RATE	FILM TYPE	SPECTRAL RANGE	SPECTRAL RESO
HIGH RESOLUTION CAMERA	480 CROWN PLATE	5° + 40° SHUTTERS IN SEQUENCE AT HALF SPEED; N.D. FILTERS	ZOOMAR HYPER-STABILIZED FL = 40 IN, f/5,6	3,2° x 3,2°	30, 45, 60 FPS	XT-PAN	VISIBLE	N.A
CINESPECTROGRAPH #213 UV-VIS	560 FUSED SILICA	360 lines/mm GRATING BLAZED AT 3200A	MAKSUTOV FL = 300 mm f/2,7	5,5 x 10,5°	5, 10, 15 FPS	4-X	,31-,62μ	3,0 Å WITH 4X
CINESPECTROGRAPH #214	642 CROWN PLATE	309 lines/mm GRATING BLAZED AT 6000A, SCHOTT OG-4 FILTER	MAKSUTOV FL = 300 mm f/2,5	5,5 x 10,5°	5, 10, 15 FPS	HSIR	,55-,88μ	6,0 Å WITH HS
FILTER WHEEL CAMERAS #1 & #2 DBM-4M1	790 CROWN PLATE	FILTERS SYNCHRONIZED BETWEEN CAMERAS	KINOPTIK APOCHROMAT FL = 100 mm f/2,5	4,2 x 5,8°	32 FPS	#1 2475 #2 HSIR	0,413-0,427μ 0,510-0,522μ 0,597-0,710μ 0,692-0,710μ 0,773-0,794μ 0,831-0,852μ	AS FILTERED
HIGH SPEED CAMERA DBM-5A	860 CROWN PLATE		KINOPTIK APOCHROMAT FL = 100 mm f/2,5	4,2 x 5,8°	64-400 FPS	2475	0,4-0,7μ	N.A
WIDE ANGLE CAMERA	920 CROWN PLATE		FL = 50 mm f/1,4	20,7 x 27,2°	20, 30, 40 FPS	2475	0,4-0,7μ	N.A.
SODIUM-D CAMERA DBM-4A	920 CROWN PLATE	FILTER	KINOPTIK APOCHROMAT FL = 100 mm f/2,5	4,2 x 5,8°	16 FPS	2475	0,5887 - 0,5897μ	N.A
BORESIGHT #1 TRAID 15 FOTOPAK	550 FWD CANOPY; WATER FREE QUARTZ		SWITAR FL = 2 IN, f/1,4	8,4 x 11°	8 FPS	2475	0,39-0,7μ	N.A.
BORESIGHT #2 KB 3A	590 AFT CANOPY; WATER FREE QUARTZ		KINOPTIK APOCHROMAT FL = 100 mm f/2,0	4,2 x 5,8°	16, 32 FPS	2475	0,39-0,7μ	N.A
BALLISTIC CAMERAS	1120 CROWN PLATE	ROTATES DOWNWARD TO STRETCH OUT STAR TRACES, BINARY CODED CHOPPING	WILD-HEERBRUGG AVIOGON FL = 6 IN, f/5,6	74 x 127° Combined	5 CHOPS/SEC PULSE WIDTH CODED	018 PLATE	0,39-0,65μ	N.A
THREE CHANNEL RADIOMETER; R-51	590 AFT CANOPY; WATER FREE QUARTZ	THREE DETECTOR/FILTER CHANNELS USING SAME PRIMARY	CASSEGRAINIAN f/4 610 mm f/0,6 FIELD LENSES	1 x 1° TRUNCATED WEDGE	280 CPS RECORDER TAPE	PbS DETECTOR	1,18-1,32μ 1,55-1,75μ 2,07-2,27μ	N.A
R-71 PHOTOMETER	860 CROWN PLATE		FL = 50 mm	1° DIA.	1330 CPS RECORDER TAPE	PHOTOMULTIPLIER S-11 & S-20	0,35-0,65μ 0,65-0,9μ	N.A.
T-9 TRACKER	550 FWD CANOPY, WATER FREE QUARTZ		CASSEGRAINIAN FL = 32,724 IN.	1,8° DIA.	700 CPS RECORDER TAPE	PbS UNCOOLED DETECTOR	1,6-2,6μ	N.A

A

TABLE II-2

STRUMENT TABLE AS OF 30 JUNE 1967

RETT RESEARCH LABORATORY

YPE	SPECTRAL RANGE	SPECTRAL RESOLUTION	MI MUM DETECTABLE IRRADIANCE	SPATIAL RESOLUTION	DYNAMIC RANGE	TYPE OF DATA	DATA APPLICATION	REMARKS
	VISIBLE	N.A.		0.0₅ MR		DETAILED RESOLUTION OF COMBINED BODY AND NEAR WAKE		
	.31-.62μ	3.0 Å WITH 4X FILM	1.0×10^{-14} W/CM^2 (for atomic line in 4000 A region)	.07 MR	5×10^3	UV AND VISIBLE SPECTRUM; TIME; INTENSITY	TIME RESOLVED SPECTRA IN UV AND VISIBLE; INTENSITY	GOOD SPECTRAL AND SPATIAL RESOLUTION BODY AND WAKE SPECTRA
	.55-.88μ	6.0 Å WITH HSI. FILM	2.0×10^{-13} W/CM^2 (for atomic line in 7000 A region)	.14 MR	10^3	VISIBLE AND IR SPECTRUM; TIME; INTENSITY	TIME RESOLVED SPECTRA IN VISIBLE AND NEAR IR; INTENSITY	GOOD SPECTRAL AND SPATIAL RESOLUTION BODY AND WAKE SPECTRA
	0.413-0.427μ 0.510-0.522μ 0.593-0.710μ 0.692-0.710μ 0.773-0.⁻94μ 0.831-0.852μ	AS FILTERED	2×10^{-13}, 4×10^{-13}, 6×10^{-13} W/CM^2 3×10^{-12}, 2×10^{-10}, 2×10^{-12} W/CM^2	1 MR 1 MR	10^4 10^3	INTENSITY IN SELECTED REGIONS IN VISIBLE INTENSITY IN SELECTED REGIONS IN IR	TEMPERATURE AND EMISSIVITY AREA WHEN CONTINUUM	
	0.4-0.7μ	N.A.	8.5×10^{-13} W/CM^2	1 MR	10^4	BROADBAND INTENSITY; TIME; RELATIVE DEPLOYMENT	VISIBLE INTENSITY; SCINTILLATION HISTORY; WAKE CHARACTERISTICS; RELATIVE SLOWDOWN	BASIC CINE TRACKING AND BORESIGHT CAPABILITY
	0.4-0.7μ	N.A.	9.5×10^{-13} W/CM^2	1 MR	10^4	BROADBAND INTENSITY; REALTIVE DEPLOYMENT	VISIBLE INTENSITY; WAKE CHARACTERISTICS; RELATIVE SLOWDOWN	
	0.5887-0.5899μ	N.A.	2.5×10^{-11} W/CM^2	1 MR	10^4	SODIUM INTENSITY; TIME	MEASURES SODIUM DOUBLET RADIATION	
	0.39-0.7μ	N.A.	--	1 MR	10^4	BORESIGHT INFORMATION FOR T-9 TRACKER		
	0.39-0.7μ	N.A.	--	1 MR	10^4	BORESIGHT INFORMATION FOR R-51 RADIOMETER		
	0.39-0.65μ	N.A.	5×10^{-13} W/CM^2	1 MR	--	POSITION OF OBJECTS; TIME; LUMINOUS INTENSITY	TRAJECTORIES; OBJECT IDENTIFICATION; INTENSITY PROFILE	SENSITIVITY DEPENDS ON TARGET RATE
OR	1.16-1.32μ 1.55-1.75μ 2.07-2.27μ	N.A.	5×10^{-12} W/CM^2 4×10^{-12} W/CM^2 5.5×10^{-12} W/CM^2 INCLUDING FILTER	N.A.	10^5/CHANNEL	R.V. INTENSITY IN IR REGION	IR INTENSITY AND SCINTILLATION HISTORY	3-GAIN AMPLIFIER ASSOCIATED WITH EACH CHANNEL
IPLIER	0.35-0.65μ 0.65-0.9μ	N.A.	S-11 6×10^{-14} S-20 3×10^{-13} W/CM^2	N.A.	10^5	INTENSITY VS TIME IN VISIBLE REGION	VISIBLE AND NEAR IR INTENSITY AND SCINTILLATION HISTORY	3-GAIN AMPLIFIER ASSOCIATED WITH EACH CHANNEL
ED	1.6-2.6μ	N.A.	5×10^{-11}	N.A.	10^5	(USED AS OPTICAL TRACKER FOR SYSTEM POINTING)		

B

b. To insure maximum data return from the system, both quantitatively and qualitatively.

c. To insure minimum downtime of the system or subsystems.

Scope

The maintenance program is designed to keep the TRAP-7 system performing to established performance criteria. These criteria will be defined by manufacturers' specifications or by specifications used for acceptance testing of the system. Procedures have been established for each instrument to cover electronic adjustment, mechanical adjustment, inspections, cleaning, lubrications, overhauling, and complete system readjustment. Performance of these procedures leads to system adjustment within the tolerances of performance criteria. Maintenance tasks and their time requirements have been established, and scheduling planned on calendar/ or mission/or running time basis. The maintenance program also establishes the necessary spare parts levels to be stocked and the test equipment required. Tasks are denoted as to whether they will be done in the field or in the laboratory or returned to a vendor for repair and overhauling. The maintenance program will be continually updated as new procedures are defined as the system changes, and as experience provides better information on the frequency required for maintenance procedures.

Implementation

The TRAP-7 system is categorized into four subsystems: Pointing Systems, Radiometer & Video Systems, Mechanical/Optical Systems, and Support Systems. Maintenance manuals are provided for each subsystem. For each element of a subsystem the following information is included:

Performance criteria
Maintenance instructions and schedule
Procedures for testing, adjustment, alignment, and calibration
Test equipment required
Reference to all drawings, manuals, and other documentation applicable to the instrumentation, and spare parts lists.

A data sheet is provided to record results of adjustments and testing where required. These are filed both on the aircraft and in the laboratory.

Premission checkouts and postmission system performance evaluation provide the first echelon of the system maintenance. The field mission report contains checklists on performance of tasks and records of per mission electronics readings. Per mission performance of portions of the system are analyzed by review of the visicorder event records both in the field and in the lab.

A maintenance log is being kept on the aircraft and a duplicate file in the laboratory. This log records the type of maintenance and corrective action required along with spare parts used.

An important part of the preventive maintenance plan is the feedback of information from various data reduction groups in the laboratory. This provides monitoring of most parts of the system on a per-mission basis. Information will be supplied from data reduction in forms of data commentaries and special evaluation reports. Continuing analysis of the data reduction feedback will allow monitoring of system drifting and will provide a tool by which systems maintenance requirements can be predicted. For the pointing system, the readouts of the boresight camera records provide a means by which the performance of the pointing system can be continually evaluated without going through the process of a complete electronics checkout. The radiometers, cameras, and support systems are constantly checked for proper operation through evaluation of data and calibration on each mission.

The advantages of monitoring system performance by data reduction are that this will: supplement periodic field and laboratory evaluations of the instrumentation; provide system performance information between scheduled electronics readjustments; allow observation of system drifting; provide a means of establishing better scheduling of maintenance for the system based on observed performance; lead to less system, subsystem, or instrumentation downtime.

Continuing analysis will be performed on the records, including the maintenance log and data sheets and information returned from data reduction. Reports will be prepared analyzing all significant malfunctions or discrepancies observed.

The maintenance charts provided for each instrument of subsystem element include a) the maintenance to be performed, b) frequency of the maintenance, c) location where it is intended to be performed, d) schedule showing when maintenance should occur, and e) compliance with maintenance schedule.

The frequency of performing maintenance procedures will be reviewed periodically as drift and malfunction history is accumulated, and may result in revising the maintenance cycles. Test, adjustment, and alignment procedures will also be reviewed and updated as required.

Evaluation of the TRAP-7 High Resolution Camera

As was noted in the previous discussion of system performance, the high resolution camera provided with the TRAP-7 system was returned to the laboratory in late February for an evaluation. The instrument consists of a 40-inch e.f.l. Zoomar hyper-stabilized optical system and a 70 mm Giannini Model V-A camera capable of framing rates of 30-45-60 frames per second. The shutter provides 5° and 40° sectors operating in sequence at half speed. A filter wheel between the optics and the camera permits the use of any one of four densities for attenuation for a given mission.

Tests were performed in the optics laboratory to determine the following parameters for the Zoomar lens:

1) Spatial Resolution
2) Optical wavefront deformation
3) Depth of focus
4) Modulation Transfer Function

The image formed by the Zoomar lens of a point source was also examined. Dynamic tests of resolution (i.e. with camera operating), using 4X and XT-Pan films, were also made in conjunction with the film plane focus test.

The tests were run to find the resolution of the lens and the camera assembly, to find the aberrations, to establish the field-of-view, and to give any other data that would help establish the parameters of the instrument. A complete report of the testing was prepared as TRAP Memorandum #4 and sent to BSD/Aerospace.

The results are as follows:

1) The Zoomar lens, which has a Rayleigh resolution limit at 5500 Å of 266 lines per millimeter (less than one arc second) resolved between 200 and 245 lines per millimeter visually (approximately one arc second) using a USAF high contrast bar target.

2) The lens is not diffraction limited, showing some spherical aberration on-axis, and coma, classical with this type of system, off-axis.

3) The image of a point source (approximately 2 arc seconds) on-axis showed considerable amounts of flare as well as color. The aberration pattern was not symmetrical and indicated that some constraint may be present on the reflector optics.

4) Depth of focus of the lens was measured as 0.008 inch.

5) The instrument, in a dynamic mode of operation, resolved 30 lines per millimeter (approximately 6 arc seconds) as determined from a visual inspection of the XT-Pan film. This was also verified by microdensitometer scans of the image from a USAF high contrast bar target. Figure II-2 shows the MTF curves of the system operating with XT-Pan and 4X films.

Possibilities for improving the performance of the system appear to be good, and we are presently in contact with the Zoomar Corporation concerning the improvement of this lens system to more closely approach its theoretical capabilities.

Gimbal Stops

Background

The stops initially installed on the TRAP-7 3-axis and 4-axis gimbals were not strong enough to arrest gimbal rotation, either in elevation or azimuth, in the event of gyro failure during operation. These gimbals are located behind large viewing windows in the main cabin of the TRAP-7, KC-135. The gimbals presently possess stops which are sufficient to stop gimbal motion in the two rotational axes (azimuth and elevation) under normal operating conditions. Gyro failure, while a remote probability, is a possibility which could occur. There have been cases elsewhere in which the existing type stops on similar gimbals have been sheared when unusually high rotational rates have been applied, and the gimbal and payload instrument proceeded to move beyond these stops. These cases did not occur aboard the TRAP-7 aircraft; however, the gimbals and payloads aboard TRAP-7 are placed close enough to the viewing windows so that if these high forces were applied and the present stops sheared, the payloads would strike the viewing windows. Under mission operational conditions, impact of the payload could possibly break the windows and cause rapid decompression of the aircraft.

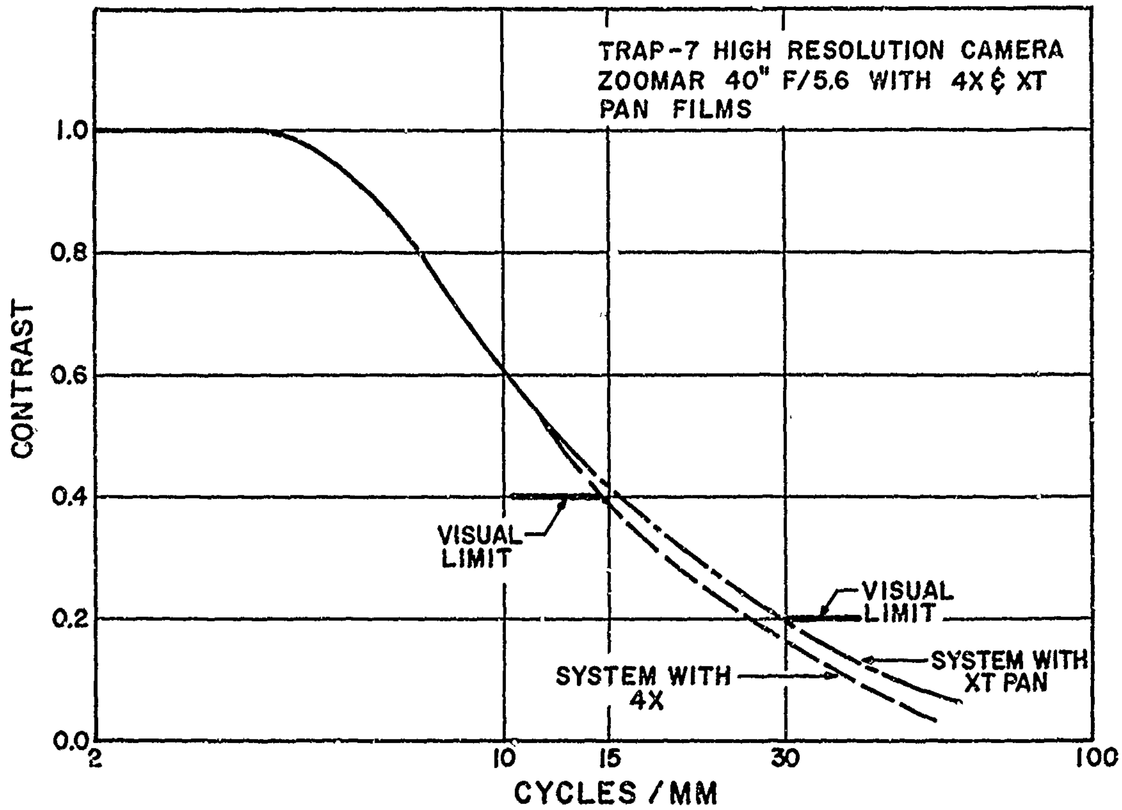


Fig. II-2 Modulation transfer function for the TRAP-7 High Resolution system using 4X film and XT-Pan film for recording media. Higher resolution is achieved with the XT-Pan, and this film has been used with the system in the field. Thirty cycles/mm results in a resolution as recorded of ~ 6 arc seconds. The visual limits shown were determined from inspection of recorded images of USAF high contrast bar targets.

The discussion which follows summarizes the design and testing of stronger stops as designed by AERL. Complete stop assemblies for all of the 3-axis gimbals and the 4-axis gimbal are now ready for installation whenever the aircraft is available. Until the new stops are installed, the crews aboard TRAP-7 are harnessed or strapped while the gimbals are actuated in-flight.

Design and Testing

The AERL-designed stops will eliminate the problem by providing much stronger stops for the gimbal elevation and azimuth axes. The basic concept is to employ rugged housings with bushings, attached to various portions of the gimbal by screws of proper strength; inside the bushings are inserts of a material (lead was chosen) which dissipate the force of the moving gimbal by extruding the cylindrical lead insert of a properly specified diameter through an orifice of smaller diameter. This method provides the excellent advantage of decelerating the gimbal at a steady force, while providing an impact decleration limited to approximately 5 g's. The design was reviewed and approved by Aerospace Corporation at a meeting in April.

Figure II-3 shows how the finished gimbal stops appear when installed. The gimbal in the photograph is identical to those on the aircraft.

The various fixtures resulting from this design can be installed on the aircraft with hand tools, and do not require removal of the gimbals from the aircraft.

Stress analyses have been performed to demonstrate that the design, both of structure and of mounting bolts, will survive the high gimbal accelerations with adequate safety factors.

Tests have shown that lead inserts (pellets) of approximately 5/8-inch in diameter and approximately 2-inches in length will be sufficient to stop the energy resulting from 3-axis rotation in azimuth, and 4-axis rotation in azimuth and elevation. A pellet of 1/2-inch diameter and 1-inch length is sufficient for the case of 3-axis rotation in elevation. Thus, pellet sizes and attendant extrusion bushings can be reasonably standardized. Further,

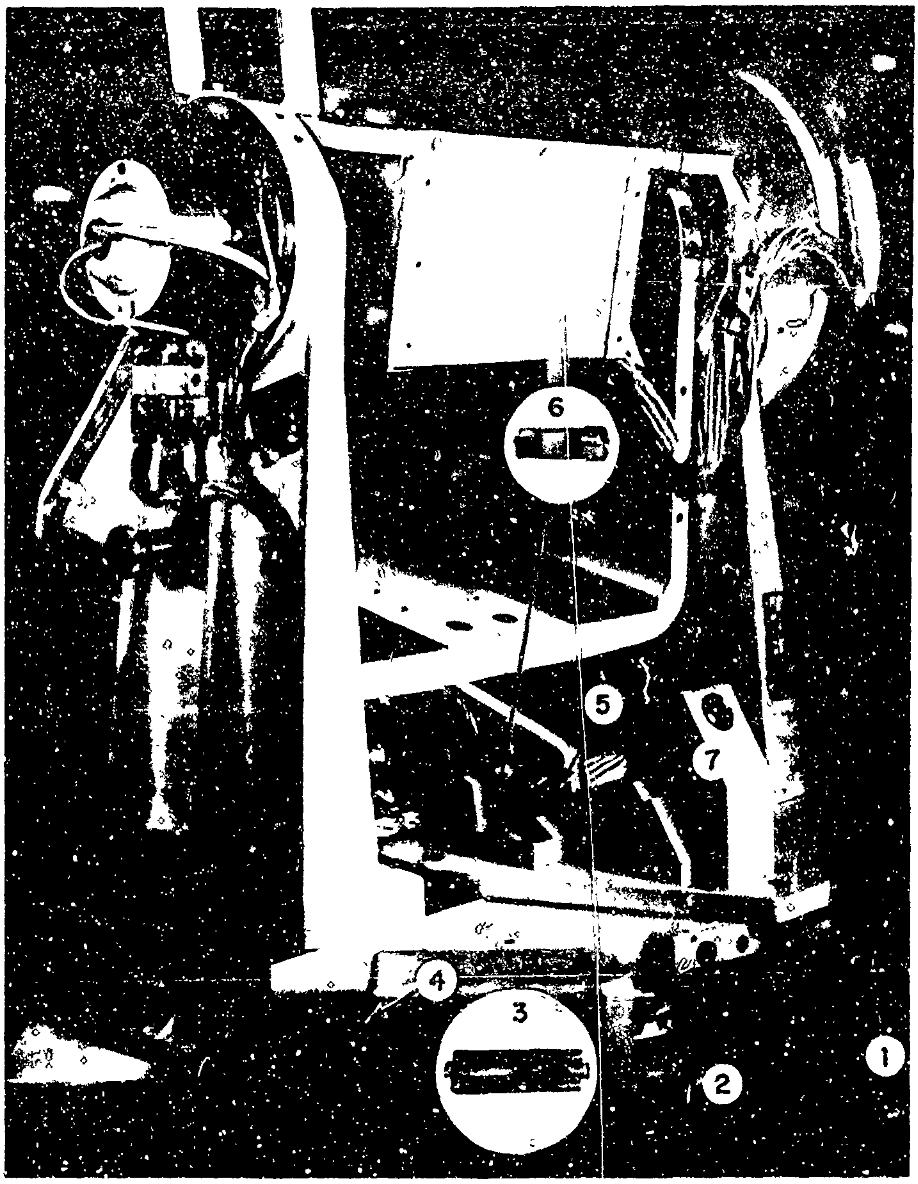


Fig. II-3 Three-axis gimbal with AERL stops installed for the azimuth and elevation axes. For azimuth rotation, a strong bar (1), attached to the moving portion of the gimbal, strikes a piston at (2) which in turn forces a lead pellet (3) through an extrusion die bushing (4) which extends beyond the housing. In elevation rotation, a special fixture with offset fingers (5) is employed to strike the lead pellet (6) which is provided with a steel cap for uniform force transfer. The housing with pellet for stopping elevation motion in the other direction is indicated by (7).

by careful design, it is possible to emplace the bushings with lead inserts on the gimbals without detriment to the gimbals.

Supplementary Fixed Camera Installation

Several types of impending missions were to involve multiple targets or were to require that optical monitoring be performed in a location apart from the usual impact areas. These situations indicated the desirability of employing a supplementary complement of fixed cameras, particularly ballistics, to provide capability for sequential ballistic camera operation and to enhance the probability of obtaining ballistic camera trajectories. It was thus decided to borrow TRAP-1's canopy complement of fixed cameras, which consisted of twin nodding ballistic cameras and three K-24 spectral cameras, for use on TRAP-7 while TRAP-1 was down for window reconfiguration and IRAN. As used on TRAP-1, these cameras had been mounted on a special frame which fit into the canopy. This package of cameras and frame could conveniently be employed behind one of the available large 27-inch diameter (clear) viewing windows on TRAP-7 by constructing a special support stand for the package and fabricating a control unit for camera actuation.

In order to locate the camera complement with proper look angles behind the TRAP-7 window, the support stand was designed and fabricated at AERL. Stress analysis for the stand was performed by AERL and subsequently accepted by ASTMP of WPAFB. During the period 20 - 22 June 1967, the mechanical portion of the supplementary camera package, as shown in figure II-4, was installed at Station No. 1000 on the TRAP-7 aircraft.

A camera control unit was fabricated for control of this instrumentation. The drive pulses (4 pps coded) for the ballistic cameras are taken from the TRAP-7 timing amplifier, the basic drive concept being the same as for the Aviogon shutters. The ballistic camera shutters are driven in a complementary mode, i.e. shutters open when the Aviogon shutters (regular TRAP-7 ballistics) are closed. The pulses (1/2 pps) for driving the K-24 spectrographs were obtained by counting down the available time code generator

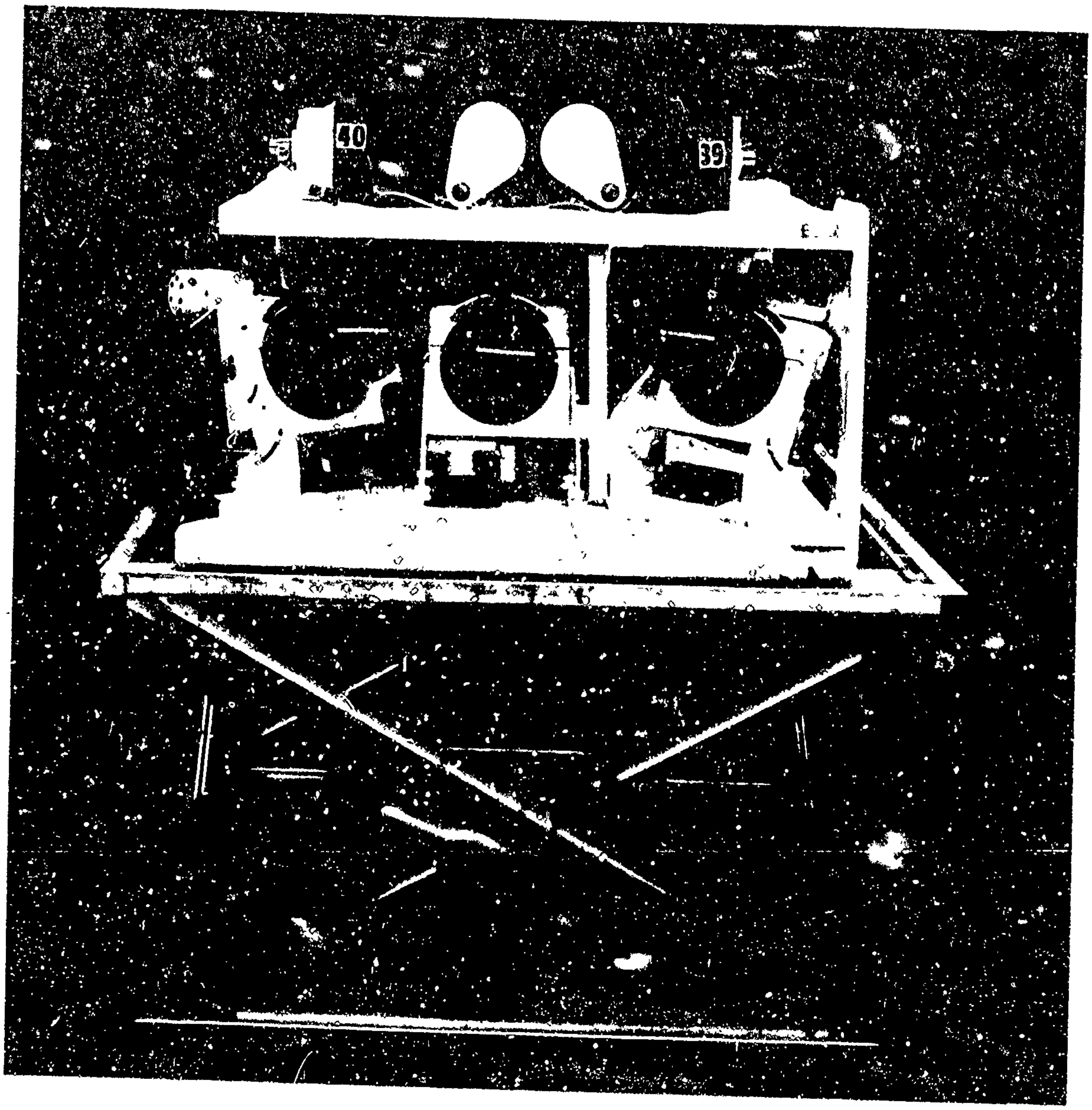


Fig. II-4 Supplementary fixed cameras shown on the special support stand fabricated for use behind a TRAP-7 window.

outputs, and were staggered to reduce surge loading of the aircraft's 28VDC system. The K-24 shutter return is mixed in the control unit and recorded on one of the TRAP-7 event charts. Installation of the electrical portion was completed on 30 June.

TASK 4.0 SYSTEM STUDIES

Subtask 4.2 System Improvement

During the operation of the TRAP-7 system, several areas which may be considered for upgrading or replacement have been noted. Descriptions are given below of these areas of interest and the reasons for considering them for system improvement.

Pointing System

The T-9 optical tracker, which is the primary system pointing instrument, lacks sensitivity and has proven difficult to use in the TRAP-7 re-entry monitoring environment. Boresighting of the system cannot be accomplished by locking on a star because of the tracker's lack of sensitivity. (This is the most desirable manner to make a final boresight of the system prior to re-entry.) The amount of time during which a typical target is bright enough for optical tracking is much less for the PbS T-9 tracker than for other available trackers.

The T-51 tracker from the TRAP-3 program will be evaluated for possible use on TRAP-7, which may also include the feasibility of converting a spare 3-axis slave gimbal to a master. In addition, possible detector substitution in the T-9 will be considered.

The buffer amplifiers in the G-10 gimbal in the main cabin have been the cause of boresight shifting noted in the field. These will be evaluated to determine the cause of the errors and recommendations made to eliminate the problem. Other component analyses will be performed as more information as to system performance is acquired.

The Westamp power amplifiers have exhibited a high failure rate, and it has also been found that there were special modifications made to

those amplifiers used on the aircraft but not made to the spares. Working with the manufacturer, efforts are being undertaken to improve the reliability and performance of these components.

Radiometer/Video Subsystems

Although there is a boresight reticle available to define the theoretical field of view of the R-51 radiometer, there is no boresight defining reticle or device associated with the R-71 photometer. Data reduction of the radiometric data and pointing system performance would be assisted if there were a "boresight shutter" or other means of permitting a radiometer to trace its precise field of view on the boresight camera film.

The R-51 radiometer decade amplifiers used have low frequency roll-off which places their response at the edge of the bandpass at the chop frequency of the radiometer. A small shift in chop frequency could cause a rather large change in system gain.

Support Systems

The Beckman WWV receiver on TRAP-7 did not have the capability of receiving range time, which is broadcast from ETR and WTR stations, and did not receive WWV (H) well on the first several missions. This unit will be replaced by a better receiver which will also have range time capability.

The tape recording system on TRAP-7 consists of three Ampex 800B recorders. This system has vacuum tube electronics, and the FM recording electronics tend to drift more than the allowable $\pm 1\%$. Consideration will be made to consider a complete new recording system which will return data to the lab which is compatible with other systems and data reduction equipment.

Mechanical/Optical Systems

The high resolution camera has been evaluated at AERL and the possibility of improving the image quality of the Zoomar lens is being discussed with the manufacturer.

A redesign of the twin ballistic camera nodding mount is desirable. Malfunctions have occurred; these were a sheared pin in the drive train, and the nodding mechanism stopped on occasion, which may be attributed to the weak nodding drive motor and a slight imbalance.

Methods of increasing ballistic camera capability for monitoring of multiple re-entries is another area of consideration.

A general review of data requirements pertinent to missile system testing and the type of data now available from TRAP-7 will be made to determine the types of new instruments for the TRAP-7 system.

TASK 5.0 CALIBRATION AND TEST

EVALUATION OF THE J216 CALIBRATOR

H. E. Koritz

Introduction

Control of TRAP-7 instrumentation was transferred from Aerojet-General Corporation to AERL during the month of February, 1967. Calibration of this instrumentation is accomplished with an on-board calibrator designated as the J216. This Task pertains to the evaluation of this calibrator to determine whether the analysis and the calibration of it, as reported by Aerojet-General correctly described its behavior, and to verify that the unit could be used for downrange calibrations.

The overall effectiveness of a calibration unit can be evaluated by comparing the expected results of a detector, when it is exposed to the unit's output radiation, with the observed results.

The choice of detector should be determined on the basis of the simplicity of its theory and the experimental equipment and the ease with which data may be obtained. The photomultiplier tube satisfies these requirements and was chosen as the evaluation unit. It has a linear response to radiation, requires only a regulated high voltage power supply and a picoammeter, and produces precise data easily.

In this report, we discuss the following subjects: (1) Using Aerojet calculated irradiances, the output of the J216 is compared with the expected response of the photomultiplier; (2) Using Aerojet calculated irradiances, the response of various TRAP-7 instruments is compared with their expected response; (3) Direct comparison is made between the results obtained with the R-71 and the photomultiplier unit, (4) Calibrations of the TRAP-7 high speed cine camera on the J216 calibrator and at the AERL calibration laboratory are compared; (5) The uniformity of samples of Inconel coated filters are investigated; (6) The types of density measured in various

systems including the J216 calibrator are investigated; (7) Internal reflections caused by inconel coated filters are discussed; (8) The J216 filters are examined; (9) absolute calibration of the J216 calibrator is investigated; and (10) the alternatives are discussed for modifying the J216 to enable us to more uniformly predict the J216's behavior.

Experimental Description

The J216 calibrator contains (1) a source focussing system consisting of two mirrors; (2) an aperture wheel consisting of three circular apertures of .04", .04", .004", and .004" in diameter identified as apertures 7, 8, and 9, respectively; two horizontal slits with dimensions .01" x .12" and .001" x .12" identified as apertures 5 and 6, respectively; two blanks; two vertical slits; and another circular aperture of a larger diameter; (3) a filter wheel containing nine inconel coated filters and a clear aperture, the clear aperture being identified as filter 1 and the remaining filters as filter 2 through filter 10, filter 10 being the most dense; and (4) a collimating system consisting of a reflecting mirror and a collimating mirror with a 40" focal length. Apertures 7, 8, and 9 are used in this evaluation with the exception of the TRAP-7 cinespectrograph where apertures 5 and 6 are used.

The photomultiplier tube chosen was the Dunmont 6291 with a S-11 surface. The auxiliary equipment was a Northeast Regulated Power Supply and a Keithley picoammeter. The output from the photomultiplier was fed directly into the picoammeter which has a time response (10% - 90%) of 1 to 3 seconds, depending on scale. The entrance aperture of the photomultiplier was 1", and a 1-3/4" diameter sleeve, 6" long, was placed around the tube for the purpose of preventing scattered light from entering the photomultiplier.

In addition, so that evaluation could be made specularly as well as broadband over the S-11 bandpass, a series of Optics Technology interference filters were placed in front of the photomultiplier. The center wavelengths are 5000 Å, 5330 Å, and 6000 Å, with a 50% bandpass of 200 Å.

Figure II-5a is a schematic diagram of the TRAP-7 J216 calibrator. Figure II-5b shows the experimental setup used in evaluating the J216 calibrator. It depicts the photomultiplier with an interference filter as they are positioned on the calibrator.

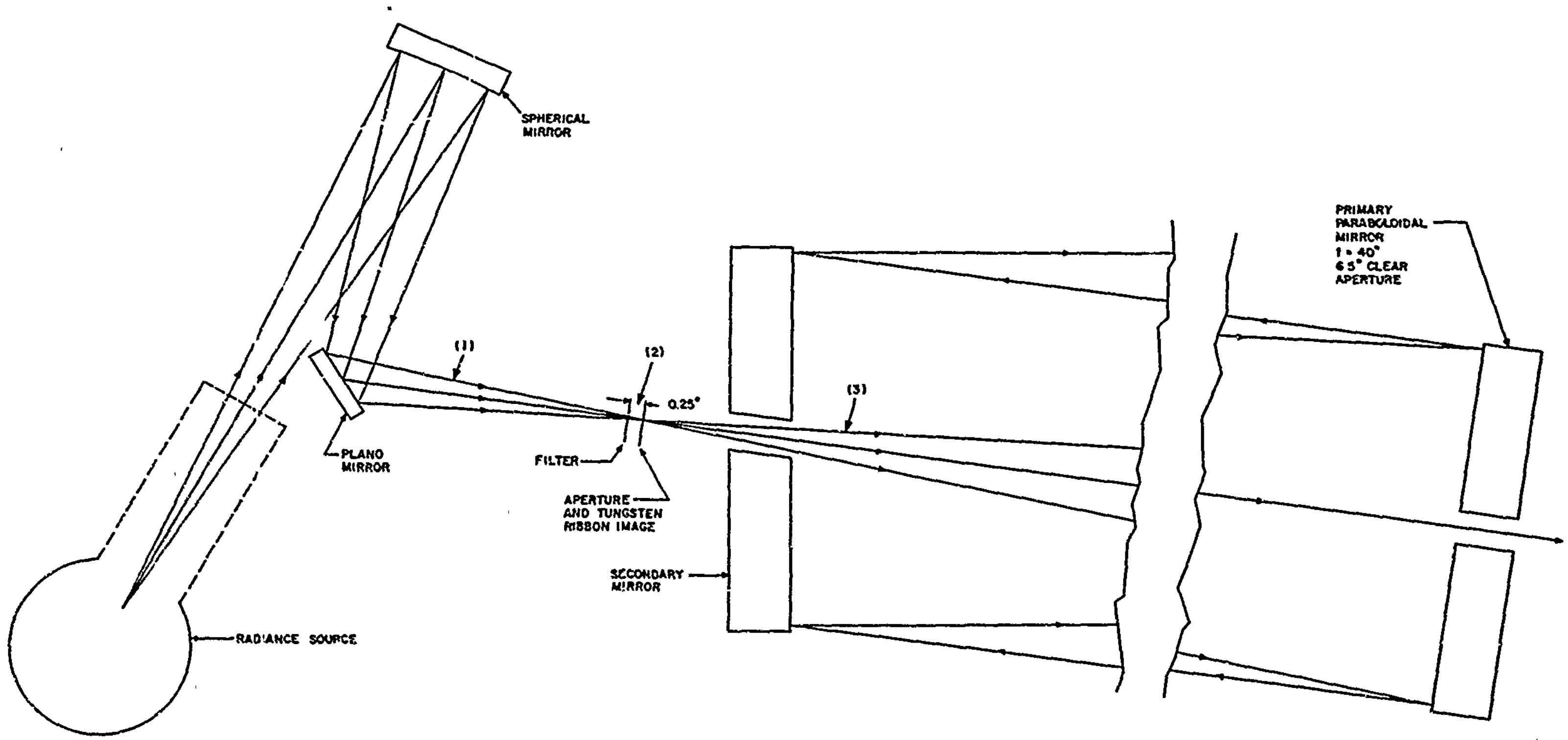


Fig. II-5a Schematic of TRAP-7 calibrator (J216).

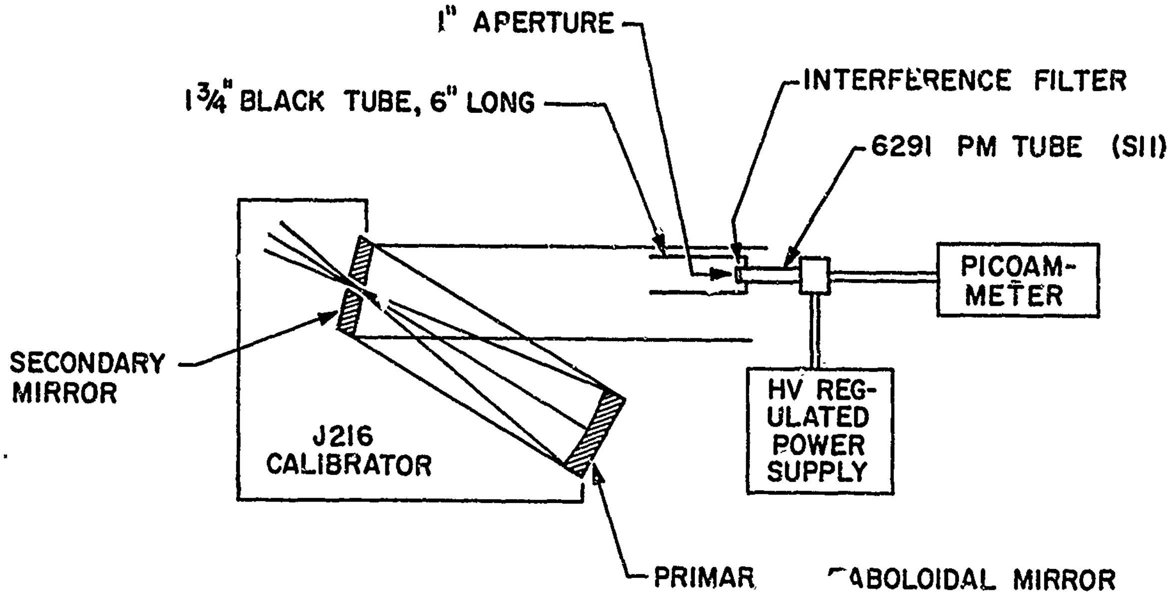


Fig. II-5b Sketch of experimental set-up on J216.

The photomultiplier linearity was checked by placing the unit in the collimated beam of the Avco 96" focal length bench and obtaining the current variation as a function of aperture area - a quantity precisely known from measurement of aperture diameter. A plot of this functional relationship should be a straight line on log-log paper with a slope of 1, since the photomultiplier current is directly proportional to the aperture area for constant radiance. Figure II-6 shows the results for a series of four experiments. The linearity is good to approximately ± 2%.

The precision of the experiment based on the standard deviation has been established to be, at worst ± 10%.

J216 Results with PM Unit

The current obtained from the PM unit when placed in the collimated beam of the J216 calibrator was plotted as a function of the Aerojet calculated irradiance values. This is shown in figures II-7 and II-8 for apertures 7 and 9 and interference filters with center wavelengths of 5000 Å, 5330 Å, and 6000 Å. The differences in current levels for the same irradiance are due to differences in the S-11 spectral sensitivity and spectral transmissions of the interference filters.

The characteristics of these curves that are indicative of the performance of the J216 calibrator, are their slopes and the reproducibility of these slopes. Comparison of these slopes to the expected slope of 1 are shown in the figures. Their disagreement with the expected slope indicates that the J216 is not producing the irradiance as calculated by Aerojet. In addition, the reproducibility of the slopes for aperture 7 and their non-reproducibility for aperture 9 is indicative of an instability in the J216 calibrator.

Correction of Aerojet Irradiance Calculations

The variation in photomultiplier current for a given aperture is a result of the variation of J216 filter transmissions. Since filter 1 is clear, the ratio of the current for each filter and filter 1 should be the measured filter transmission in the J216 calibrator system. If the scatter in the slopes of aperture 9 and the reproducibility of slopes of aperture 7 can be shown to be present similarly in the current ratios for these apertures, one must conclude that the filters are not transmitting in the manner predicted by Aerojet.

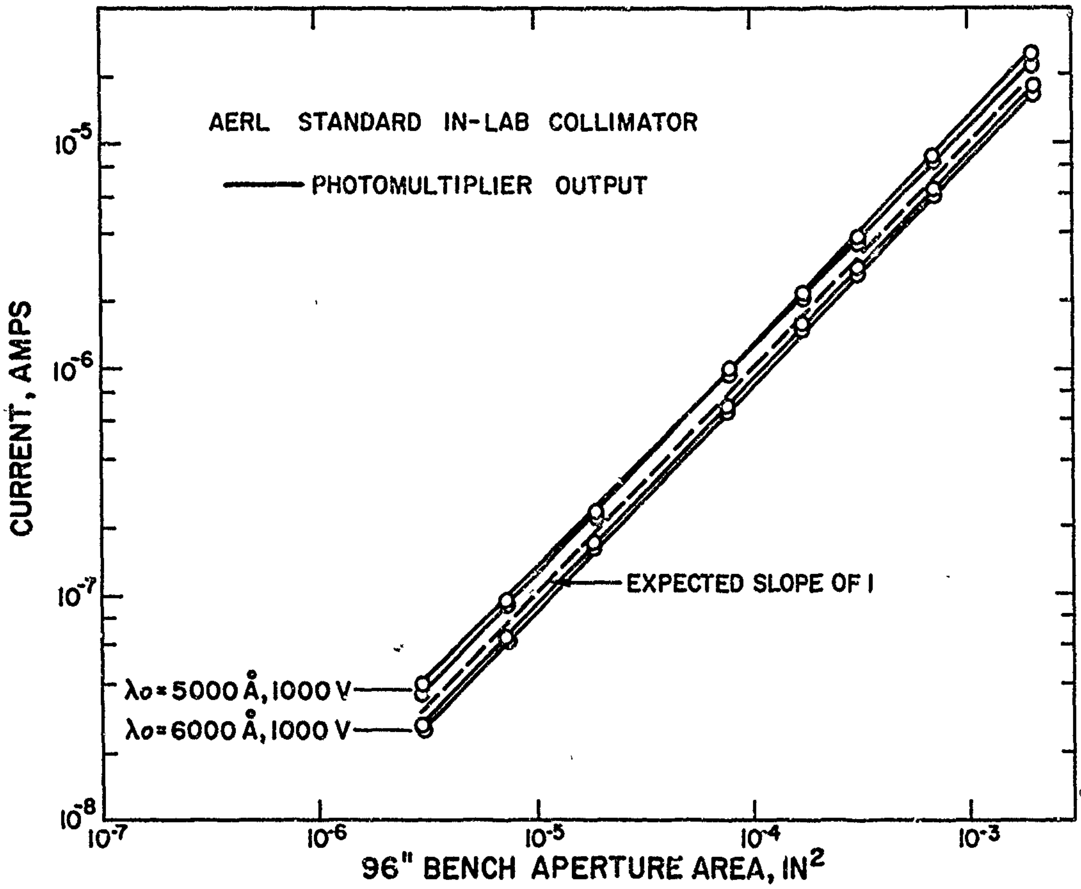


Fig. II-6 Photomultiplier response curve for AERL 96" bench showing linearity.

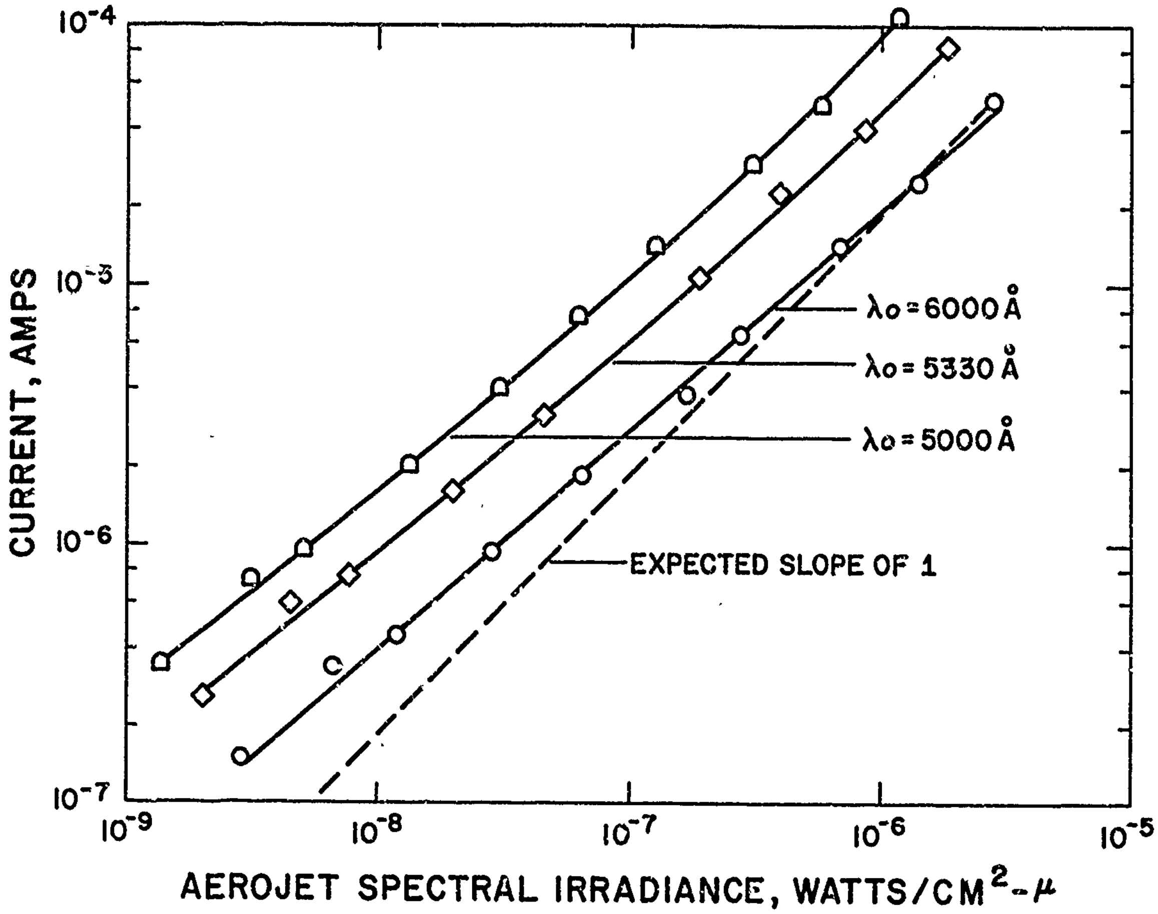


Fig. II-7 PM Output on J216 for Aperture-7.

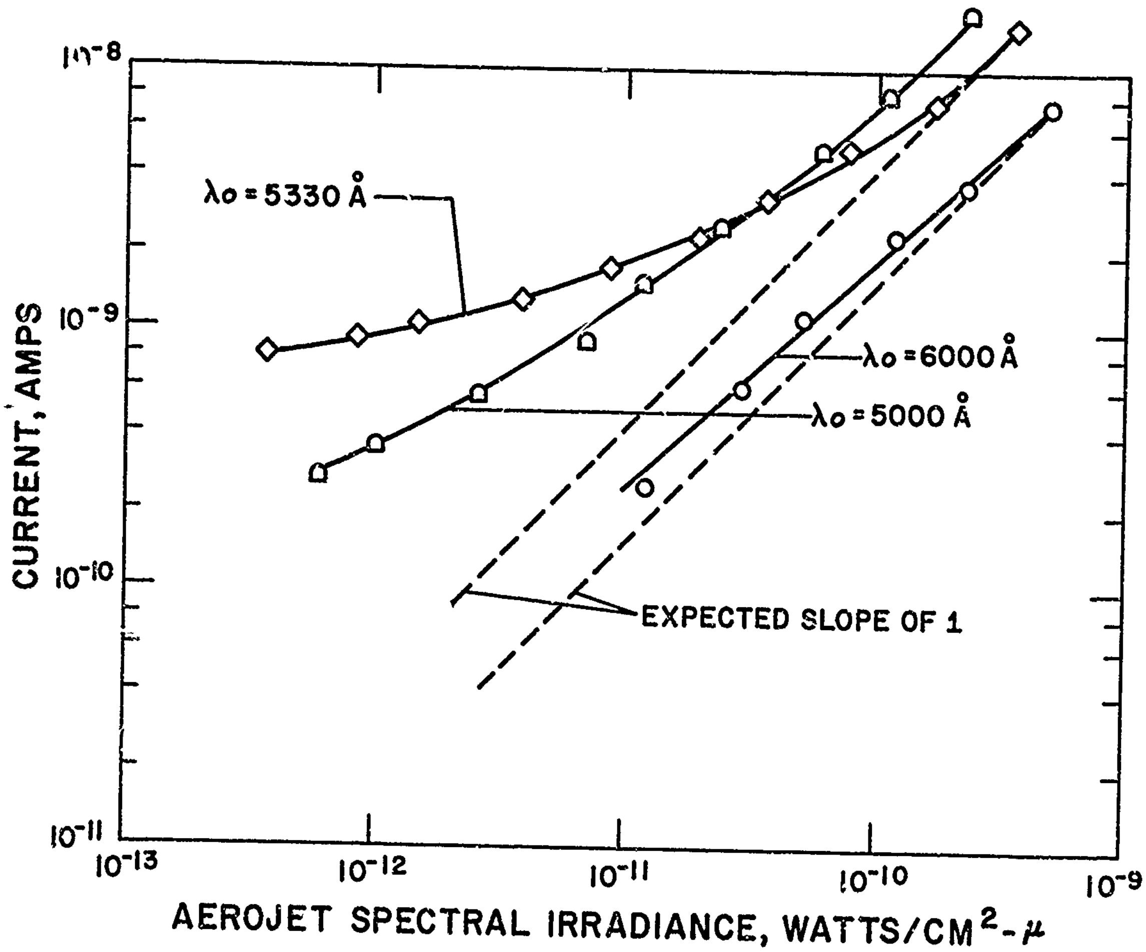


Fig. II-8 PM Output on J216 for Aperture-9.

Figure II-9 shows the current ratio for a series of six experiments for apertures 7, 8, and 9. It is seen that the scatter increases for smaller apertures and lower transmitting filters. As a result the transmissions as measured by the photomultiplier were used to correct Aerojet transmissions. These corrections are shown in Table II-3 for the 5000 Å curves of figures II-7 and II-8 is the filter transmission. By applying these corrections to each point and if this is the cause of the poor results, one expects the slopes to be corrected to a value of 1.

Figure II-10 is a plot of apertures 7, 8, and 9 showing their output as a function of Aerojet calculated irradiances. The result which makes it impossible to relate a current to an irradiance. Application of the correction factors of Table II-3 produces the expected slope for each aperture and results in a single curve for apertures 8 and 9. The reason for aperture 7does not precisely coincide with apertures 8 and 9. Nevertheless, these results indicate that the aperture areas as measured by Aerojet are approximately correct.

Corrections were made similarly to results of a broadband experiment in which no filters were used. In this case, the irradiance is obtained by averaging the spectral irradiance over the S-11 spectral response curve. It was assumed that the S-11 response for the 6291 photomultiplier used in the evaluation unit is the same as that shown by Aerojet in the TRAP-7 Summary Test Report, June 1966. The results are shown in figure II-11, the corrections producing the expected results. Note that the Aerojet point for filter 10 does not fall on the uncorrected curves for apertures 7 and 8. Investigation has shown this point to have been incorrectly calculated by Aerojet. The corrected point is shown in the figure and it is seen that it now falls on both the corrected and uncorrected curves.

TRAP-7 Instrument Calibration Corrections

The filter corrections were applied to various TRAP-7 instruments whose calibrations were obtained on the J216 calibrator. In each case, the calibration resulted in the same discontinuity in going from aperture to aperture as was seen in the photomultiplier results above. In each case

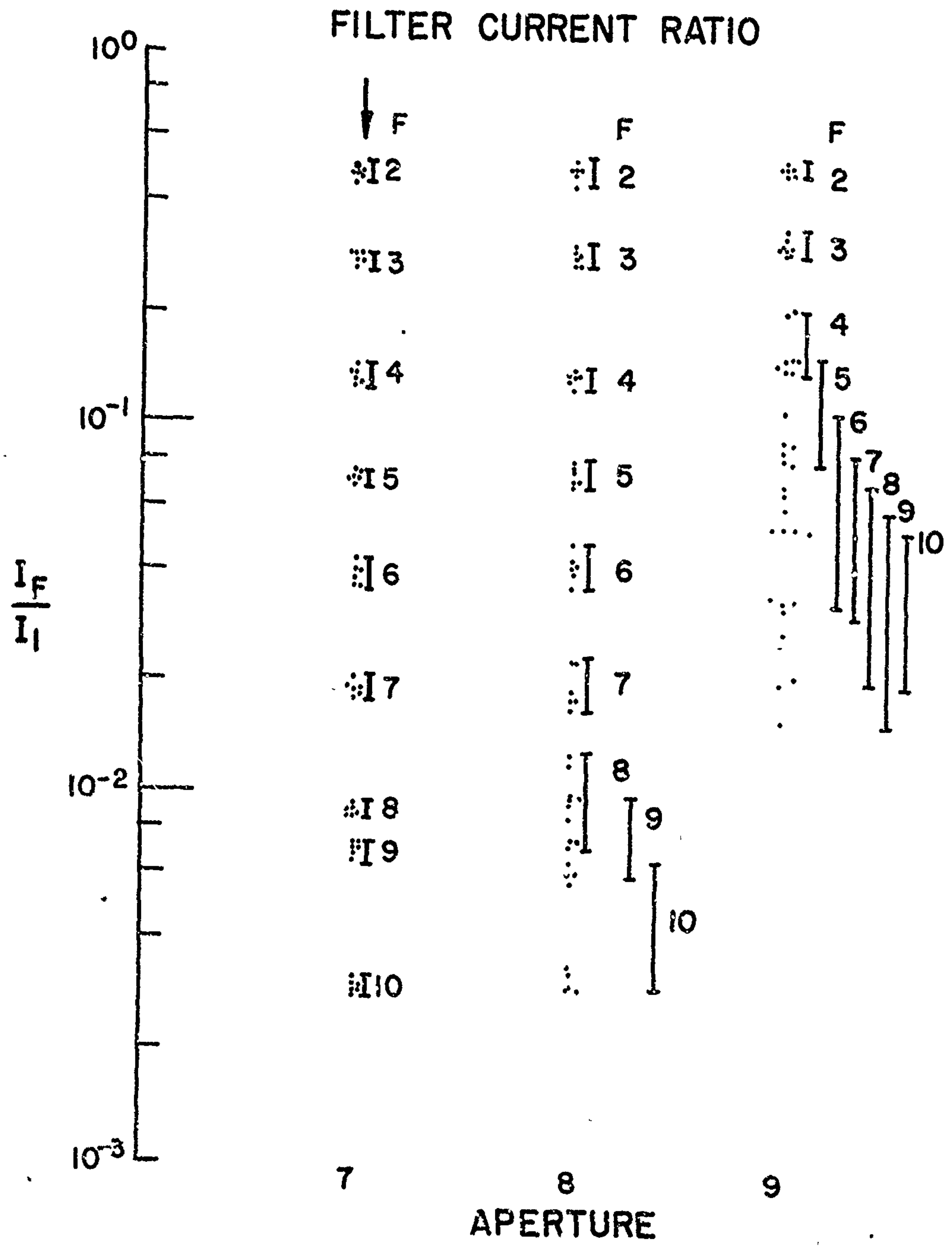


Fig. II-9 Ratio of PM Unit current for I216 Filters and Filter 1, showing scatter in data.

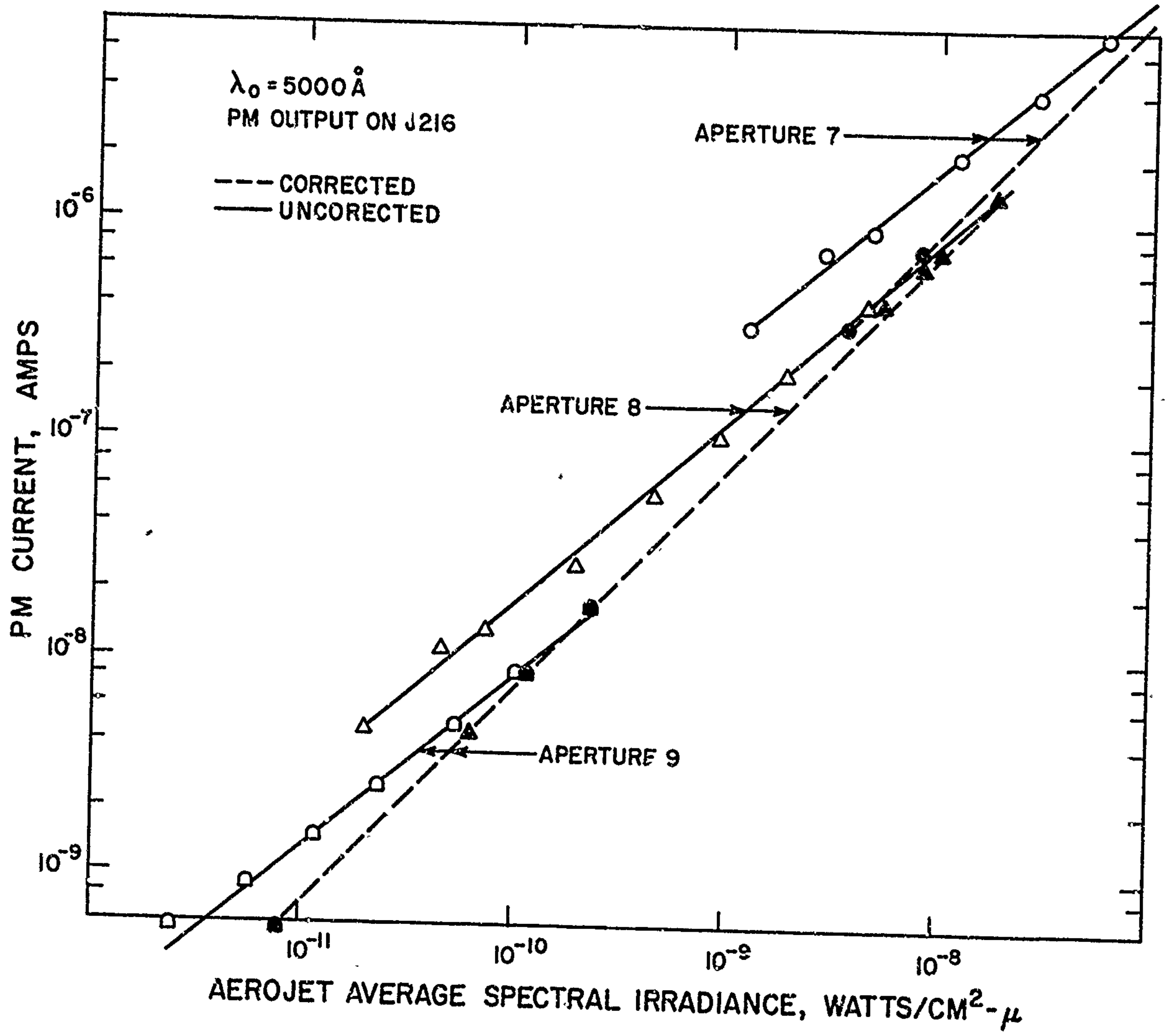


Fig. II-10 PM Output on J216 at λ_o 5000 Å and the effect of filter corrections.

TABLE II-3

J216 FILTER CORRECTIONS, λ_o 5000 Å

Filter	^{T} P. M. Aperture 7	^{T} P. M. Aperture 8	^{T} P. M. Aperture 9	^{T} Aerojet	Corr. Aperture 7	Corr. Aperture 8	Corr. Aperture 9
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	.454	.443	.491	.452	1.00	.98	1.09
3	.264	.300	.297	.243	1.09	1.23	1.22
4	.127	.143	.152	.100	1.27	1.43	1.52
5	.068	.075	.091	.053	1.28	1.42	1.72
6	.036	.040	.054	.024	1.50	1.67	2.25
7	.019	.019	.033	.010	1.90	1.90	3.30
8	.0087	.0096	.020	.0041	2.12	2.34	4.88
9	.0068	.0075	.016	.0024	2.83	3.12	6.67
10	.0030	.0032	*	.0010	3.00	3.20	*

* Signal Less Than 1.5 Times Noise Current

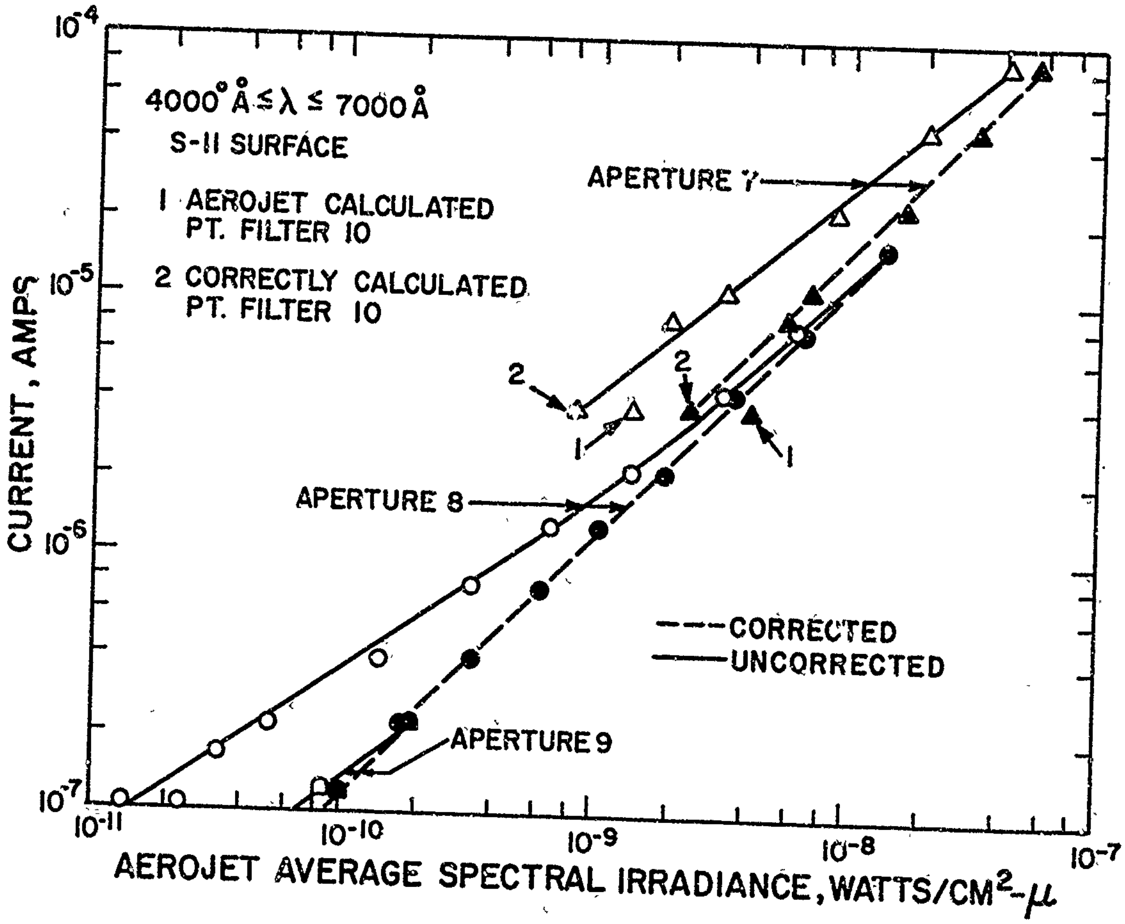


Fig. II-11 PM Output on J216 for S-11 bandpass and the effect of filter corrections.

where the response of the instrument could be predicted, the J216 calibration did not produce the expected results. The filter corrections applied to this data gave the expected results.

Table II-4 shows the corrections which must be applied to the horizontal slits, apertures 5 and 6. These apertures are used to calibrate the cinespectrographs on TRAP-7. The expected result is a slope of γ.

Figure II-12 is a calibration of a cinespectrograph on TRAP-7. Plotted is the Seidel Function of the spectral irradiance for $\lambda = 5000\text{Å}$. The discontinuity in the curve for different apertures is evident. In addition, the slopes of $\gamma = 1.24$ differ from the expected γ of 1.41 as measured with a step table. Application of the filter corrections of Table II-4 produces an approximately single curve with a slope of $\gamma = 1.43$.

The photomultiplier experiment showed that the filter corrections may have substantial scatter, particularly for aperture 9. It is therefore desirable to obtain the filter corrections for each TRAP-7 instrument simultaneously with its calibration. This could be accomplished with the photomultiplier.

Unfortunately, this was not possible and in order to apply the corrections obtained with the photomultiplier in the above experiment to subsequent TRAP-7 calibrations on the J216, a set of maximum and minimum filter corrections were determined. The hesitancy to simply average is exactly because of the scatter and the observation that an entire set of filter-current readings resulted in either a set of minimum corrections or a set of maximum corrections. Table II-5 shows the set of corrections adopted by Avco for the subsequent TRAP-7 instrument calibrations. Note the small differences between the minimum and maximum corrections for aperture 7 and the large differences for aperture 9.

The Aerojet calibration of the wide angle camera which appears in the TRAP-7 Summary Test Report, June 1966 exhibits the same discontinuity between apertures as observed in the photomultiplier experiment. Application of the minimum corrections to this data effectively eliminates the discontinuity. This is shown in figure II-13.

TABLE II-4

J216 FILTER CORRECTIONS, CINESPECTROGRAPHS

Filter	*τ P. M. Aperture 5	τ P. M. Aperture 6	τ Aerojet	Corr. Aperture 5	Corr. Aperture 6
1	1.00	1.00	1.00	1.00	1.00
2	.493	.500	.452	1.09	1.11
3	.282	.291	.243	1.16	1.20
4	.140	.145	.100	1.40	1.45
5	.076	.078	.053	1.43	1.47
6	.041	.043	.024	1.71	1.79
7	.020	.021	.010	2.00	2.10
8	.010	.011	.0041	2.44	2.68
9	.0081	.0083	.0024	3.38	3.46
10	.0038	.0040	.0010	3.80	4.00

*Average of 6 Runs

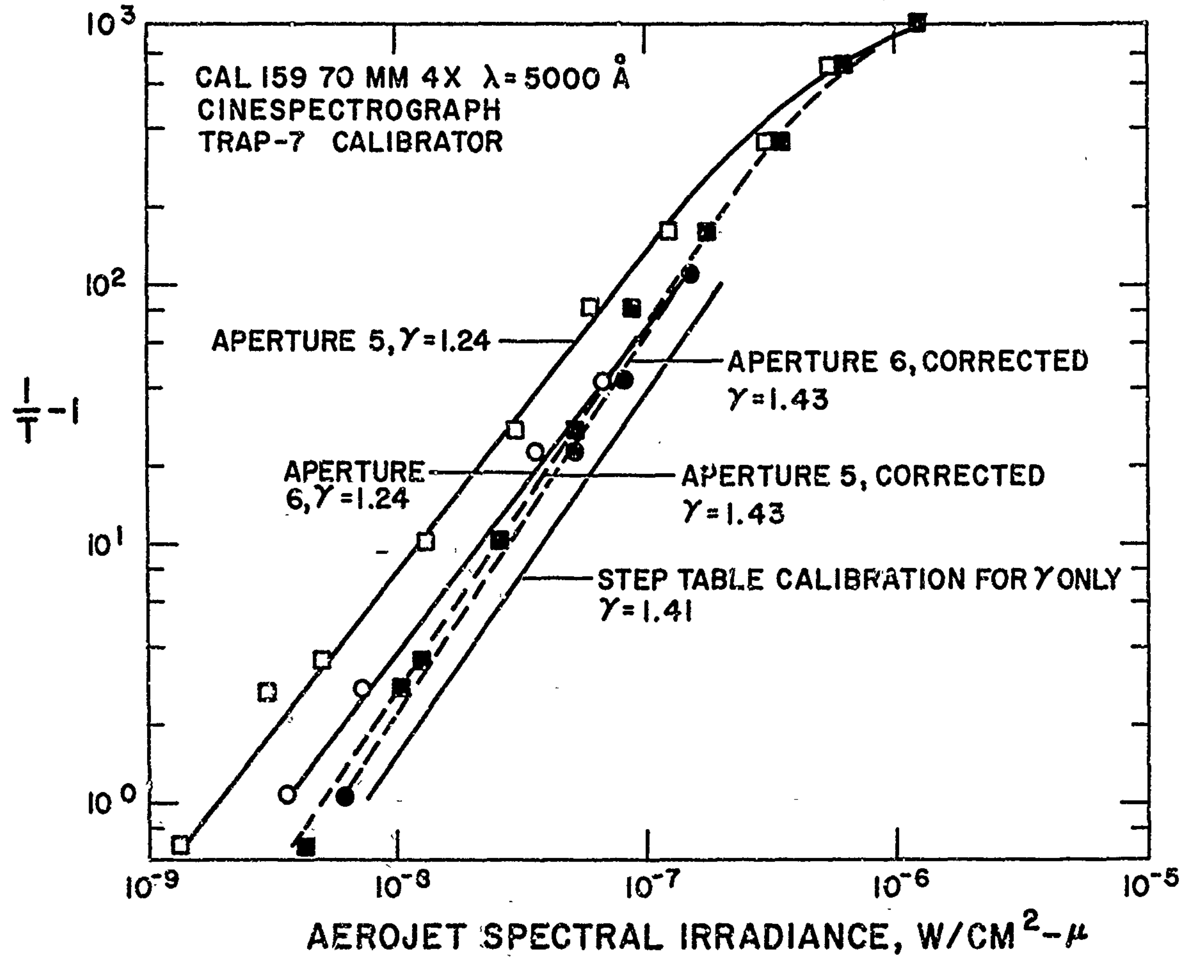


Fig. II-12 Barnes cinespectrograph film response curve in terms of seidel function (T = Transmittance) obtained on the J216 and the effect of filter corrections.

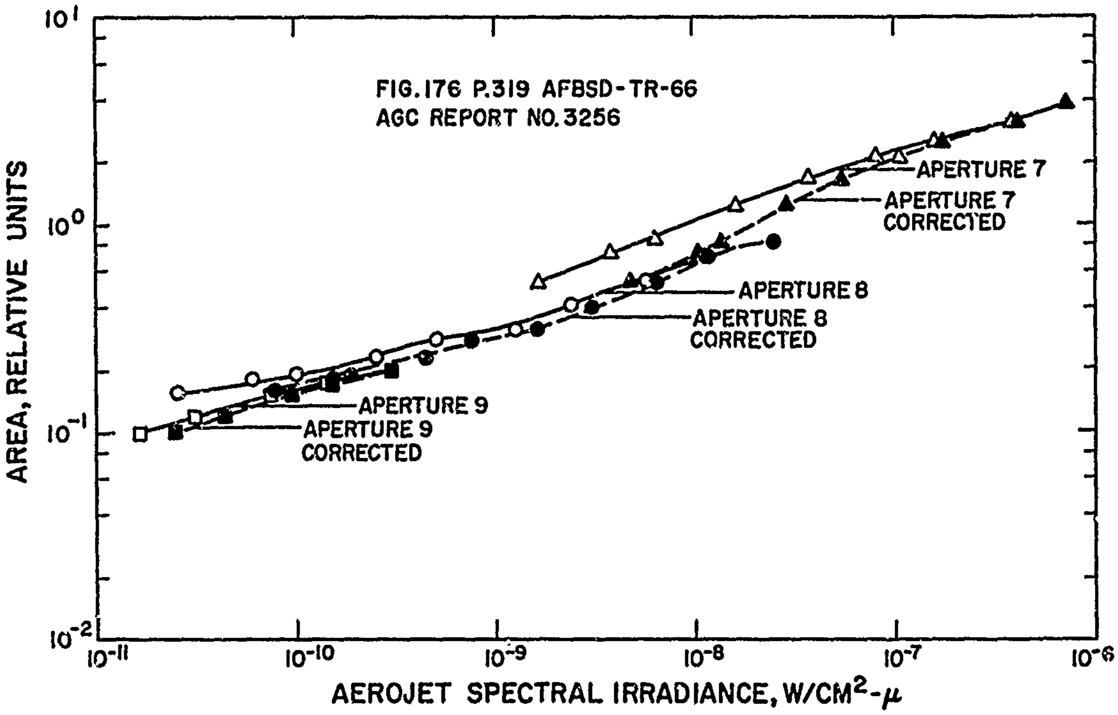


Fig. II-13 Aerojet photometric calibration of wide angle camera on J216 and the effect of filter corrections.

The R-71, which is also a photomultiplier unit containing an S-11 surface photomultiplier and an S-20 surface photomultiplier, ought to exhibit the same behavior as the photomultiplier unit used in the evaluation of the J216 calibrator. Figures II-14, II-15, and II-16, show this to be the case.

Although the minimum-maximum corrections were applied, exact corrections can be obtained for those cases where an output voltage was obtained for filter 1, the clear aperture, by simple ratioing the voltage for the remaining filters to it. When this is done, the points fall exactly on the line with a slope of 1. This is seen in figure II-16.

Again, the lines for each aperture do not exactly coincide after the corrections, perhaps indicating some area inaccuracy. Again, in figure 10, the incorrect Aerojet irradiance for the S-11 band for filter does not fall on the uncorrected curve. The corrected point for aperture 8 improves the fit to the uncorrected curve while for aperture 9 it falls exactly on the uncorrected curve.

Filter corrections were also applied to a calibration of the TRAP-7 high speed camera made on the J216 and a comparison made of the corrected curve with an AERL calibration performed on the same camera. The calibrations at AERL were made on an optical bench with a 96" focal length collimating mirror. Figure 13 shows that the corrections essentially eliminate the discontinuities between apertures, resulting in an approximately single curve. Aperture 7 is resolved and it is not clear that one ought to expect this aperture to provide a continuation of apertures 8 and 9 both of which are unresolved, although the differences between the corrected curves of apertures 7 and 8 are comparable to the differences between the corrected curves of apertures 9 and 8. Figure II-17 also shows that the corrected TRAP-7 curve is approximately a factor of 2.5 lower than the curve obtained on the AERL 96" bench. The reason for this discrepancy is in the process of being determined.

Discussion

At this stage of the investigation, the observed data and the differences in the filter transmissions as reported by Aerojet and as measured in the

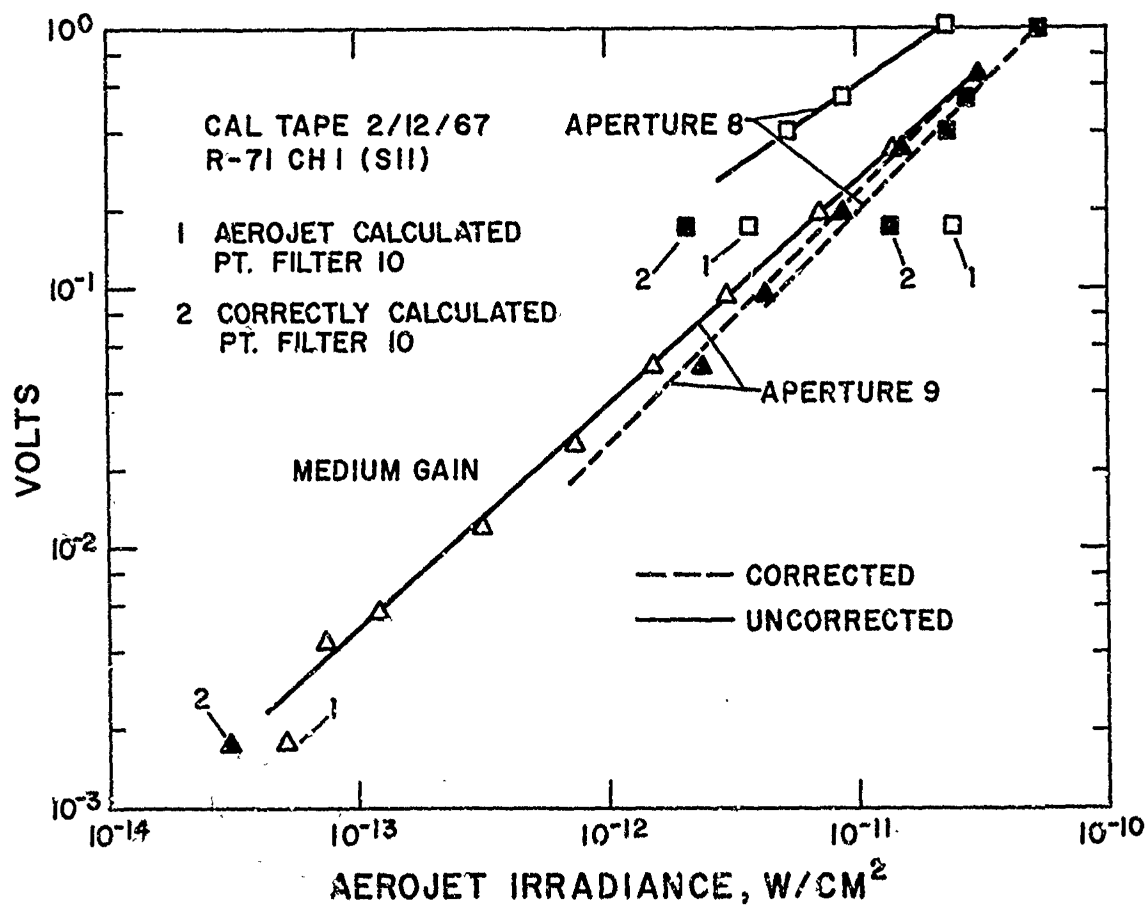


Fig. II-14 R-71 Photometer, Channel 1, response curve obtained on the J216 and the effect of filter corrections.

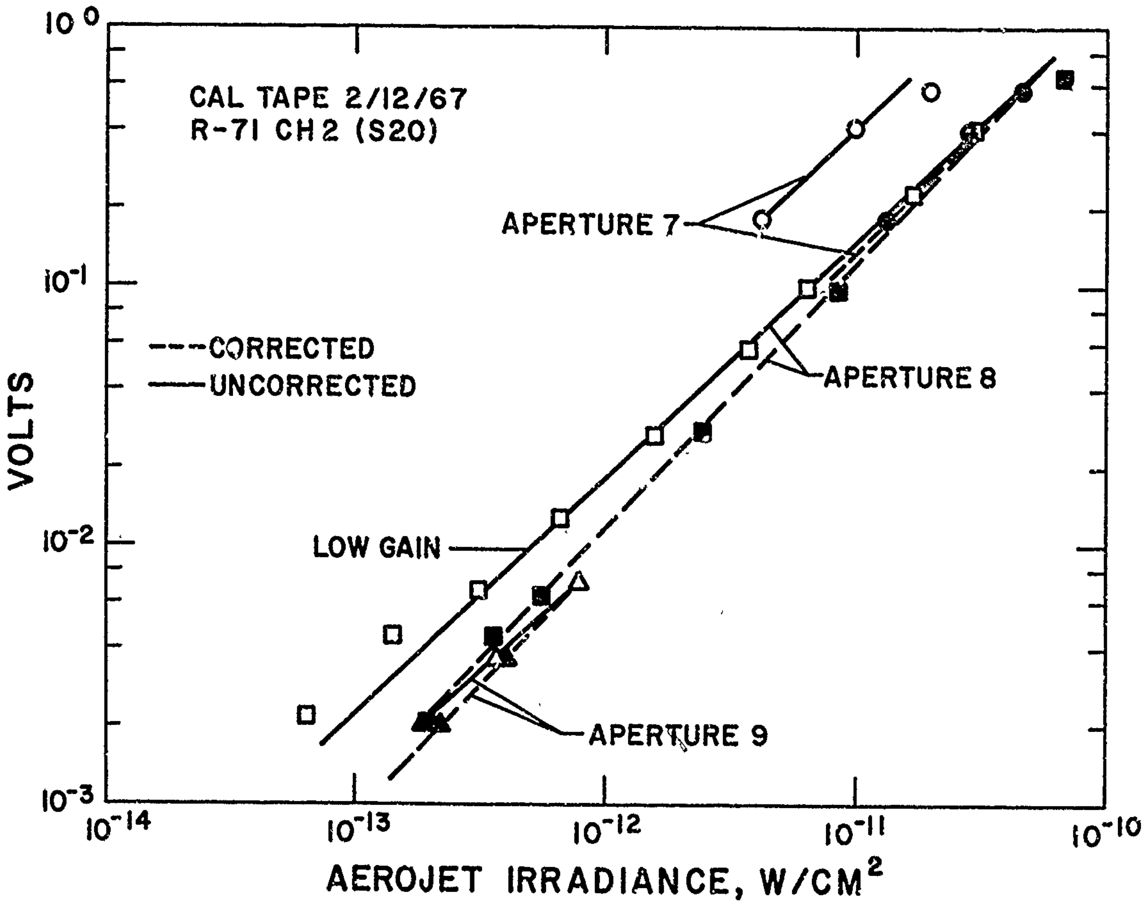


Fig. II-15 R-71 Photometer, Channel 2, response curve obtained on the J216 and the effect of filter corrections.

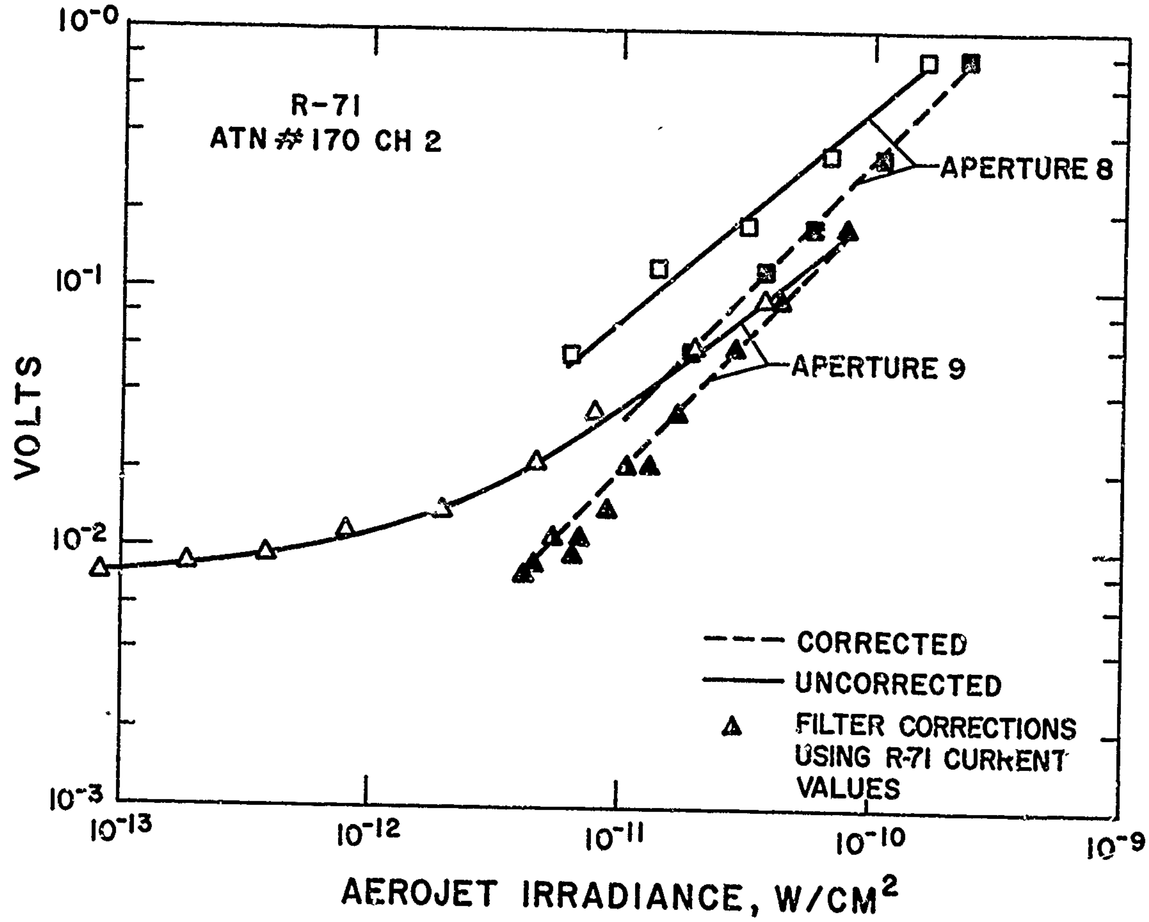


Fig. II-16 R-71 Photometer, Channel 2, response curve obtained on the J216 and the effect of filter corrections. This shows the wide scatter in Aperture-9 data observed with the PM unit used in the evaluation.

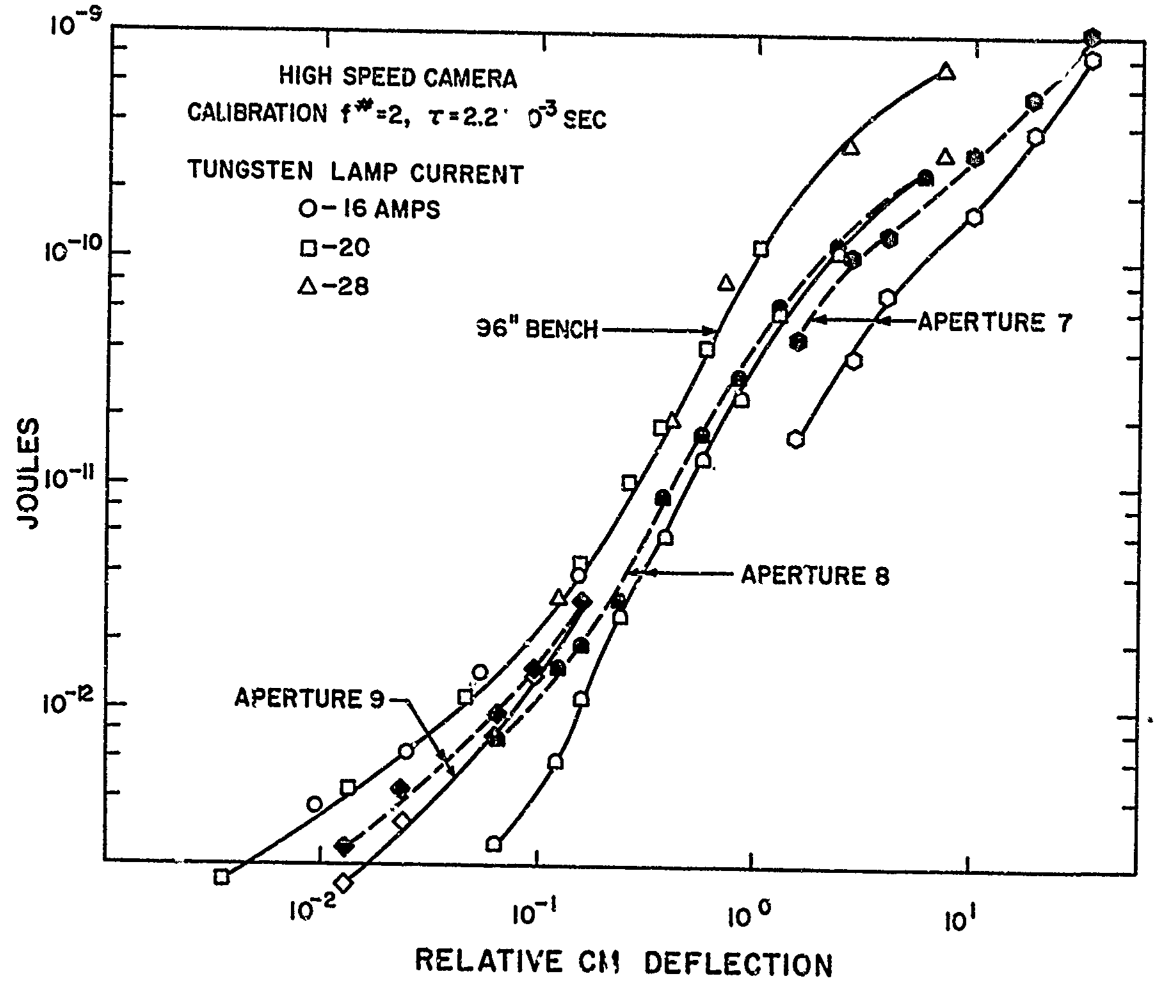


Fig. II-17 High speed camera response curve obtained on J215 and the effect of filter corrections. The corrected curve is compared to the calibration curve obtained on the AERL standard in-lab collimator (96" bench).

J216 calibrator system could be attributed to three causes: (a) the differences between the J216 calibrator system and the system in which the filter transmissions were measured, and (b) pinholes and/or irregularities in the inconel coatings of the filters. (c) The filter transmissions were measured incorrectly.

Observation of the data shows that: (1) The filter correction increases with increasing density for a given aperture; (2) The filter corrections, (particularly the maximum corrections), in many cases increase with decreasing aperture for a given filter; (3) The scatter, manifested in the differences between maximum and minimum corrections, increases with decreasing aperture for many filters.

Referring to (a), the filter transmissions as reported by Aerojet were measured in a Beckman Spectrophotometer, Model DK-2, an instrument which apparently measures a specular type density. The terms specular and diffuse generally do not apply to reflective type filters, e.g., Inconel coated filters, provided the coating and the quartz surface are smooth. If this is not the case, there will result a diffuse transmission similar to that for photographic type neutral density filters. In addition, the presence of reflective type filters in an optical system can produce internal reflections.

Either or both of these effects can effectively increase the filter transmissions and satisfy "observed data" statement (1). Diffusion of the transmitted light increases with filter density, resulting in an increase in correction factor with density. Similarly, the percentage of reflected radiation increases somewhat with density. One expects a systematic type error, independent of aperture. Table II-5 indicates that such an error may be occurring. See, for example, the minimum corrections for apertures 7 and 8.

Referring to (b), "observed data" statements (1) and (2) are consistent with the assumption of the presence of pinholes and/or irregularities of some dimension whose contribution to increasing the filter transmission increases (1) with the increasing density of the filter, and (2) as the aperture diameter approaches the aggregate of the pinholes and/or irregularities dimensions. This does not presuppose that a single pinhole is not the cause of the increased transmission.

TABLE II-5

J216 FILTER CORRECTIONS, CINE CAMERAS, RADIOMETERS,

APERTURE 7

Filter	*Data Points	$\tau_{PM_{min}}$	$\tau_{PM_{max}}$	$\tau_{Aerojet}$	$Corr_{min}$	$Corr_{max}$
1	6	1.00	1.00	1.00	1.00	1.00
2		.480	.500	.452	1.06	1.11
3		.264	.283	.243	1.09	1.16
4		.127	.143	.100	1.27	1.43
5		.068	.074	.053	1.28	1.40
6		.036	.043	.024	1.50	1.79
7		.018	.020	.010	1.80	2.00
8		.0086	.0093	.0041	2.10	2.27
9		.0065	.0072	.0024	2.71	3.00
10		.0028	.0031	.0010	2.80	3.10

APERTURE 8

Filter	*Data Points	$\tau_{PM_{min}}$	$\tau_{PM_{max}}$	$\tau_{Aerojet}$	$Corr_{min}$	$Corr_{max}$
1	6	1.00	1.00	1.00	1.00	1.00
2		.484	.527	.452	1.07	1.16
3		.272	.309	.243	1.12	1.27
4		.126	.143	.100	1.26	1.43
5		.069	.081	.053	1.30	1.53
6		.036	.048	.024	1.50	2.00
7		.017	.024	.010	1.70	2.40
8		.0072	.013	.0041	1.76	3.17
9		.0062	.010	.0024	2.58	4.17
10		.0030	.0066	.0010	3.00	6.60

APERTURE 9

Filter	*Data Points	$\tau_{PM_{min}}$	$\tau_{PM_{max}}$	$\tau_{Aerojet}$	$Corr_{min}$	$Corr_{max}$
1	6	1.00	1.00	1.00	1.00	1.00
2	6	.491	.530	.452	1.09	1.17
3	6	.300	.352	.243	1.23	1.45
4	6	.142	.211	.100	1.42	2.11
5	6	.080	.153	.053	1.51	2.89
6	6	.034	.113	.024	1.42	4.71
7	4	.033	.087	.010	3.30	8.70
8	3	.020	.070	.0041	4.88	17.1
9	3	.016	.060	.0024	6.67	25.0
10	2	.021	.053	.0010	21.0	53.0

*Signals greater than 1.5 times noise current

Neither (2) nor (b) explains "observed data" statement (3), the scatter in data as the aperture is decreased. The scatter must be explained on the basis of two conditions which must exist simultaneously, namely: (1) the presence of pinholes, and (2) the variation in the positions of the apertures and filters with respect to each other. Although this positioning is not critical when the diameter of the pinhole is small compared to the aperture diameter, this is not the case when the diameters are comparable as for aperture 9.

Inconel Coatings

To continue the investigation an examination was made of the uniformity of the surfaces of two Inconel coated filters of neutral density 2.0 and 3.0 manufactured by Thin Film Products, Incorporated and available at the laboratory.

To determine the uniformity of the coatings, a photomicrograph was taken of the density 3.0 filter, and microdensitometer traces made across the surfaces of both filters with a General Aniline and Film microdensitometer. The results are shown in figures II-18, II-19, and II-20.

The photomicrograph clearly shows the presence of pinholes of the order of .04mm and inhomogeneities in the density 3.0 filter. The dark string-like structures are dirt on the lens or filter. Figure II-19 shows the density variation across the same filter. Note the presence of a pinhole at the point marked A transmitting at 100%, with other less-transmitting pinholes in its vicinity. A density change between 3.0 and 2.8 represents a factor of 1.6 increase in transmission, while a change between 3.0 and 2.6 represents a factor of 2.5. The order of the dimensions of the non-uniformities are indicated in the figures.

Figure II-20 shows a similar behavior for the density 2.0 filter, but with less variation. Comparison of the microdensitometer trace of the Inconel coated filter of density 3.0 with a trace of a Kodak Wratten Gelatin shown in figure II-21 shows the uniformity of this latter type of filter.

Specular and Diffuse Density

To determine what type of density the J216 was measuring and whether it depended on position within the system, the Kodak Wratten filter of figure II-21 was taken to the TRAP-7 aircraft on June 5th, and placed in the J216

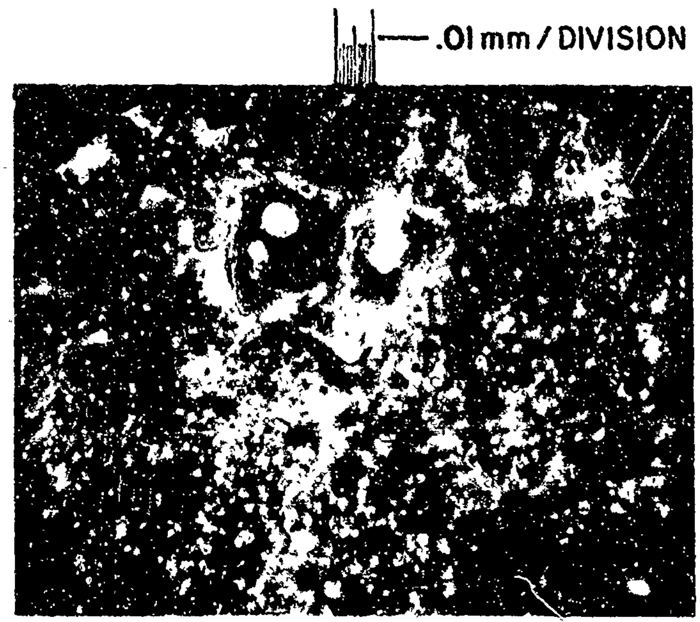


Fig. II-18 Photomicrograph of a thin film products inconel coated filter, N.D. = 3.0.

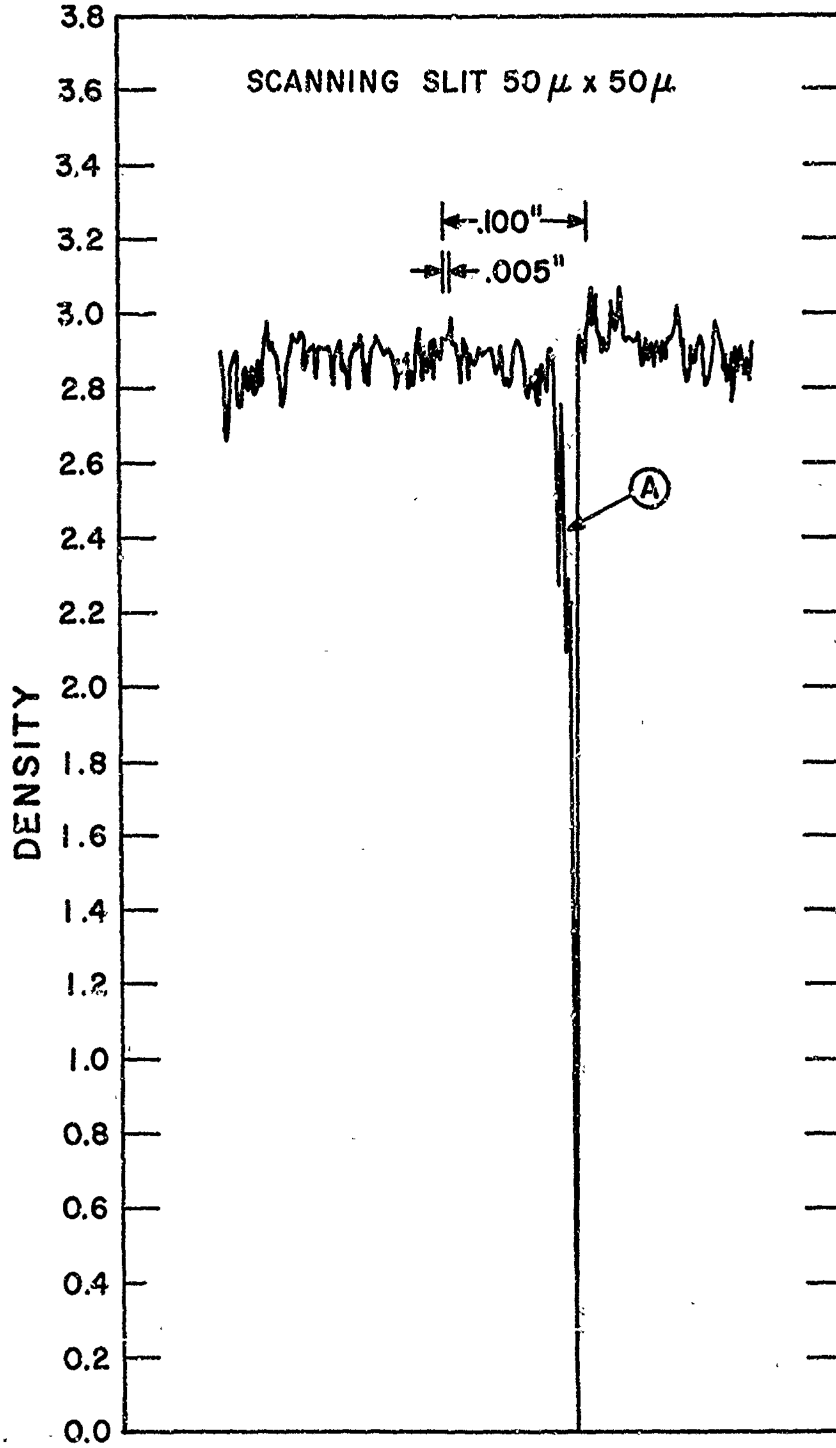


Fig. II-19 GAF Microdensitometer trace of thin film products inconel coated filter, N. D. = 3.0.

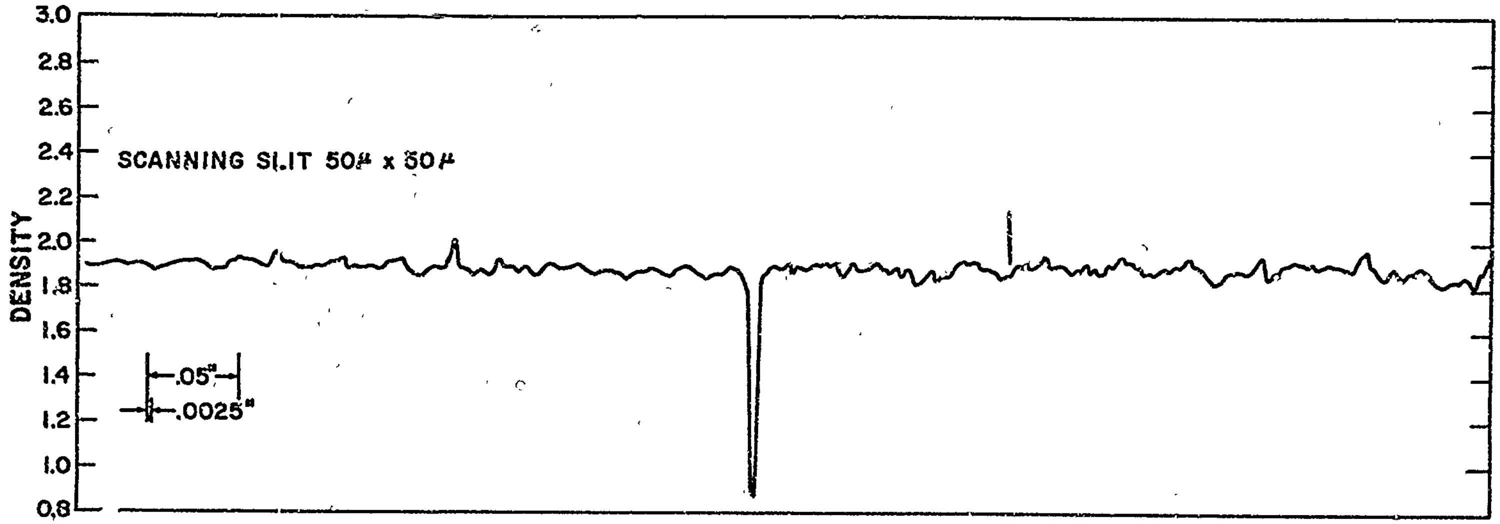


Fig. II-20 GAF Microdensitometer trace of thin film products inconel coated filter, N. D. = 2. 0.

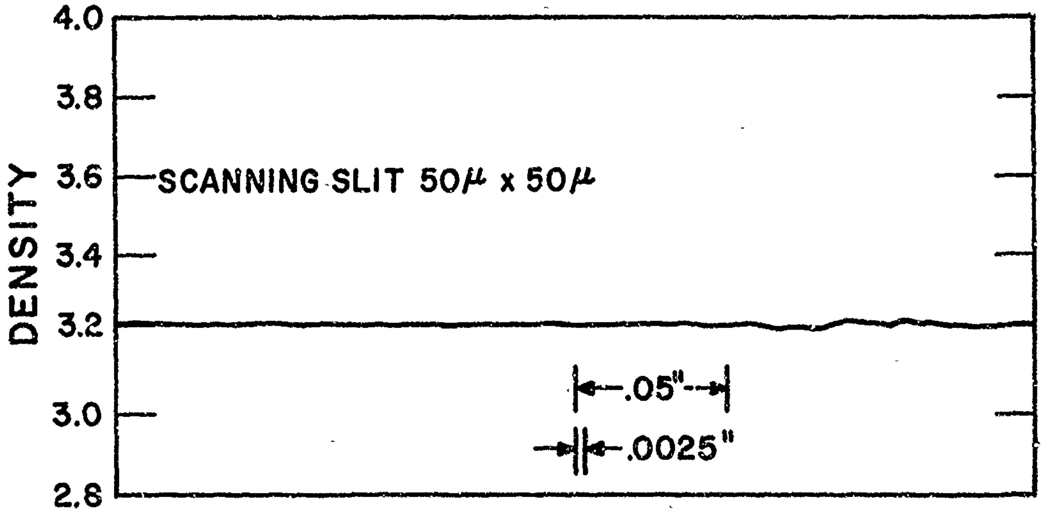


Fig. II-21 GAF Microdensitometer trace of Kodak Wratten Gelatin Filter, N. D. = 3. 0.

calibrator in three positions: (1) immediately in front of the plane mirror, (2) between the filter wheel and aperture wheel, and (3) at the exit of the hole in the secondary mirror. These positions are also indicated in figure II-5b. In each case, the transmissions as measured by the R-71 photometer was approximately 6×10^{-4} corresponding to a density of 3.22, indicating that it was independent of position in the J216.

The spectral transmission of the Kodak filter was measured on a Cary 14 spectrophotometer, an instrument very similar to the Beckman spectrophotometer. To compare the spectral transmission with the broadband transmission measured with the R-71 and GAF microdensitometer requires knowledge of the spectral irradiance of the source, the spectral transmission of the optical elements, and the spectral sensitivity of the phototube of the GAF and the R-71. The broadband transmission is given by

$$T = \frac{\int_0^\infty H_\lambda \tau_\lambda S_\lambda \, d_\lambda}{\int_0^\infty H_\lambda \, S_\lambda \, d_\lambda} \qquad (1)$$

where H_λ is the spectral irradiance of the source which is assumed to be either a black body or grey body, τ_λ is the spectral transmission of the filter, and S_λ is the normalized shape function which includes the optical elements transmission and the phototube sensitivity.

The GAF microdensitometer uses an RCA 931A phototube with an S-4 surface, while the R-71, detector 1, is a tube with an S-11 surface. Typical normalized sensitivity curves are shown in figure II-22. It is seen that they are similar in shape.

The black-body temperatures of sources used in densitometers and also in calibrators like the J216 have maximum spectral irradiance at a wavelength between 1.0 and 1.5 with the spectral irradiance rising rapidly from the blue to the red. Application of sensitivity curves similar to those in figure II-22 would show that the product S_λ H_λ peaks at approximately 5500 Å and approaches very close to zero rapidly at approximately 3500 Å. Thus, it is seen from the transmission curve that the contributions to the integral in the numerator from the regions below approximately 4500 Å (and above 6000 Å because the S – curve is approaching zero) is small and the transmission measured broadband by the above systems is approximately the

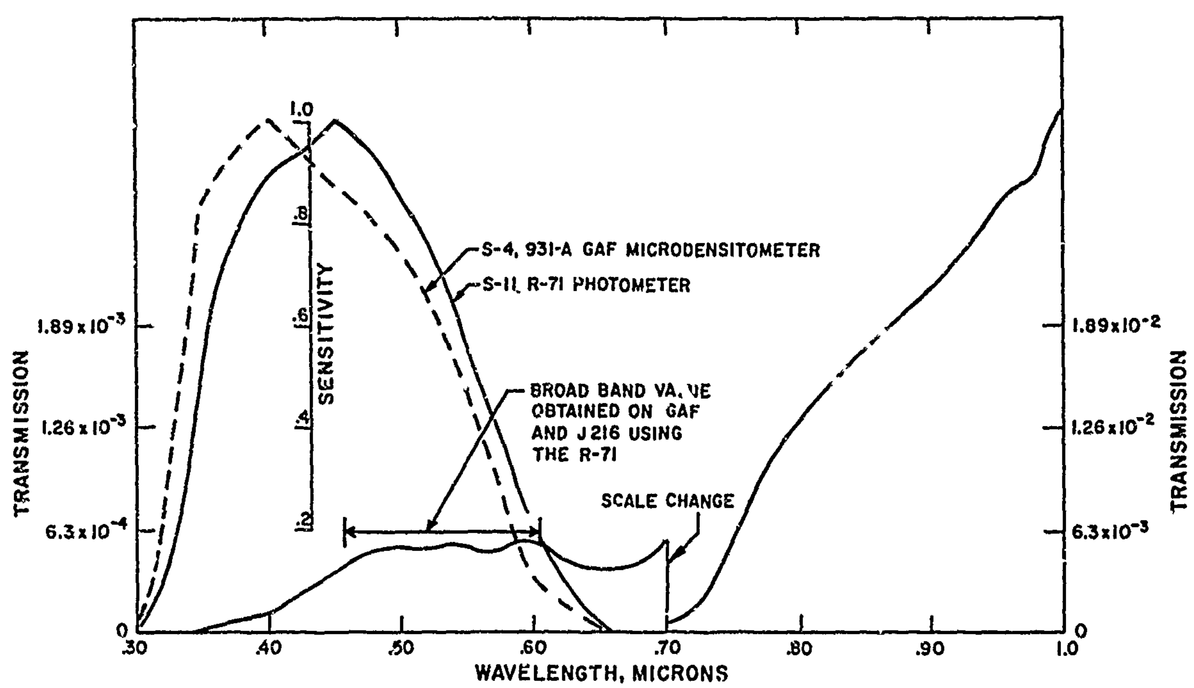


Fig. II-22 Cary 14 Spectrophotometer trace of Kodak Wratten Gelatin Filter, N.D. = 3.0. Shown are typical spectral sensitivity curves for the GAF Microdensitometer and R-71 photometer photomultipliers. These curves in combination with their tungsten source radiance distribution corresponds to a spectral transmission shown by the horizontal line.

constant value of 5×10^{-4} shown in figure II- 22 . This value compares favorably with the value of 6×10^{-4} (shown in fig. II-22 as a horizontal line over the approximate band contributing to the integral of Equation (1) obtained on the GAF microdensitometer and the J216 calibrator.

Internal Reflections

The effect of internal reflections on the observed data is difficult to ascertain. Reasonable values of reflection from Inconel filters appear to be on the order of 50%, independent of density. The presence of these reflections was clearly observed back at the tungsten lamp source on the visit to the TRAP-7 aircraft on June 5, 1967. However, discussion below will show that these reflections do not provide an important contribution to the observed differences.

Discussion

Observation of the figures shows that approximately the same densities (D = 3.22) were measured on the GAF microdensitometer, the Cary 14 spectrophotometer, and the J216 for the Kodak Wratten filter of density 3.0. Since the density of 3.0 corresponds to a diffuse density, the result indicates that these instruments measure a specular type density. The fact that the J216 density agrees with the Cary 14 and probably the Beckman would indicate that the cause of the differences intransmission between Aerojet and that measured on the J216 is probably not due to density measurement difference.

The effect of internal reflections on the increase in transmission is somewhat more subtle, but on the basis that the percentage of reflected radiation is independent of density, one expects a constant error or correction factor. Even if all the reflected radiation were repassed through the filter, one would not obtain the magnitude of errors observed for aperture 7, where the data is reproducible. This would indicate that the cause of the differences in transmission between Aerojet and that measured on the J216 is probably not due to internal reflection differences in their density measurement.

On the basis of the above discussion, it appears that there remain two possible causes of the observed differences: (1) Homogeneities and (2) incorrect measurement of the filter transmissions. The presence of inhomogeneities places a severe requirement on the placement of the filter in the optical system. Placement of the filters in the J216, shown in

figure II-5b, close to the image of the tungsten ribbon, results in the production of a nonuniform tungsten ribbon image. The reason for placing filters in parallel beams is that every point of the object will have the same transmission history through the filter. For uniform filters, placement in the J216 is independent of position. This was adequately demonstrated in the placement of the Kodak Wratten filter in various positions of the J216; no variation in output signal was observed.

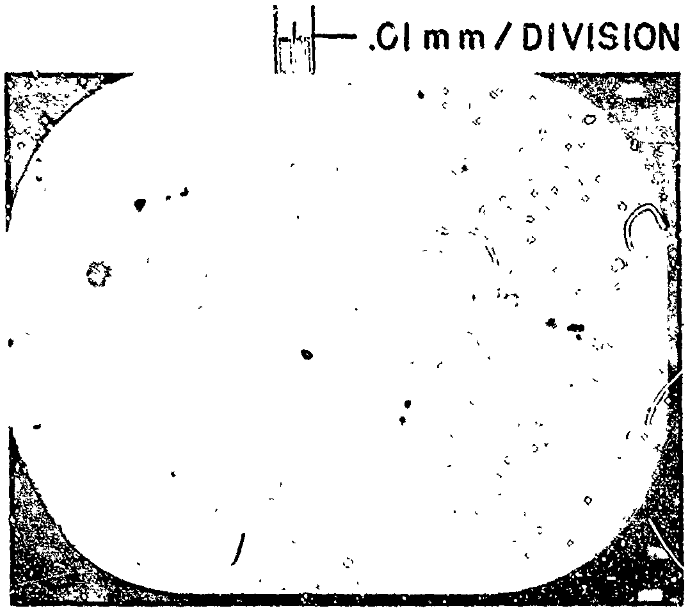
For a non-uniform image, the dimension of the aperture relative to the inhomogeneities on the image becomes significant in determining the observed transmission. This applies as well to the positioning of the aperture with respect to these inhomogeneities, variation in positioning causing scatter in transmission values.

In addition, the presence of these non-uniformities makes it advisable that the transmission measurements be made over the area to be used in the calibrator. The Beckman measures over a region of approximately 6 mm square while the Cary 14 can be adjusted up to a beam dimension of 3.2 mm x 15.8 mm. A smaller region than this in the system, depending on the number and location of the pinholes or inhomogeneities, and the regions dimensions compared to these irregularities, could produce a greater transmission value than the measured value.

J216 Filters

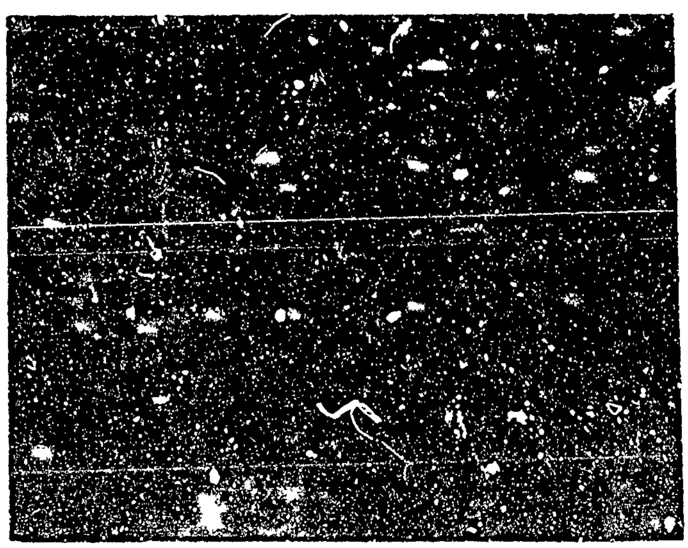
The filter wheel was subsequently removed from the J216 calibrator on June 17th and returned to AERL for the purpose of determining whether the observations suggested above would be confirmed. Figures II-23a, b and c are photomicrographs taken of filters 4, 7, and 10. Filters 0 and 10 consist of a combination of two filters to obtain the desired density. It is seen, as suspected, the filters contain numerous pinholes and scratches. Inspection of the remaining filters showed the same conditions to be present.

It was indicated above that the General Aniline and Film microdensitometer, the J216 and Cary-14 spectrophotometer measure essentially the same type of density i.e., a type of specular density. It was of interest to compare the densities of the J216 filters measured on these transmission measuring instruments with the values obtained on the J216 using the photomultiplier unit. Figure II- 24 compares the spectral transmission of the



FILTER 4

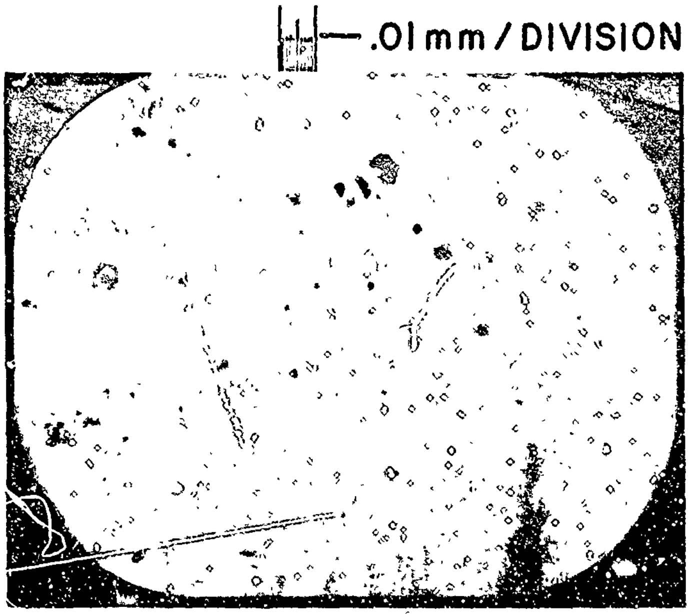
Fig. II-23a Photomicrographs of J216 Calibrator Inconel Coated Filters (Filter 4).



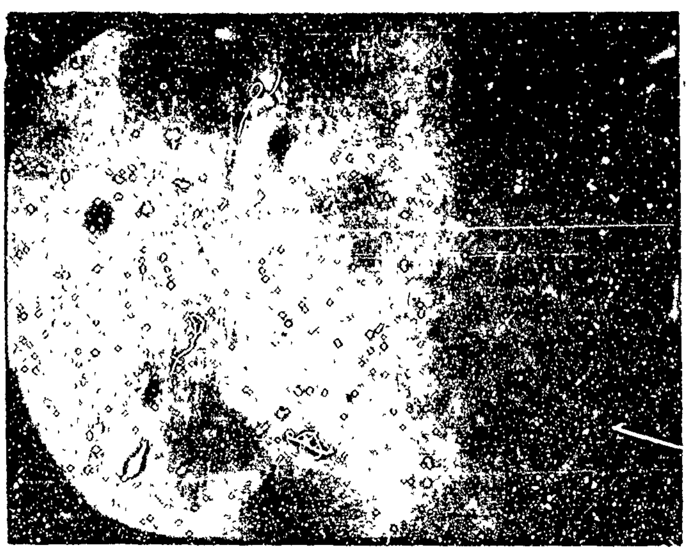
FILTER 7

Fig. II-23b Photomicrographs of J216 Calibrator Inconel Coated Filters (Filter 7).

R-9101



FILTER 10 A



FILTER 10 B

Fig. II-23c Photomicrographs of J216 calibrator inconel coated (Filter 10.) Filter 10 consists of two filters designated above as 10A and 10B.

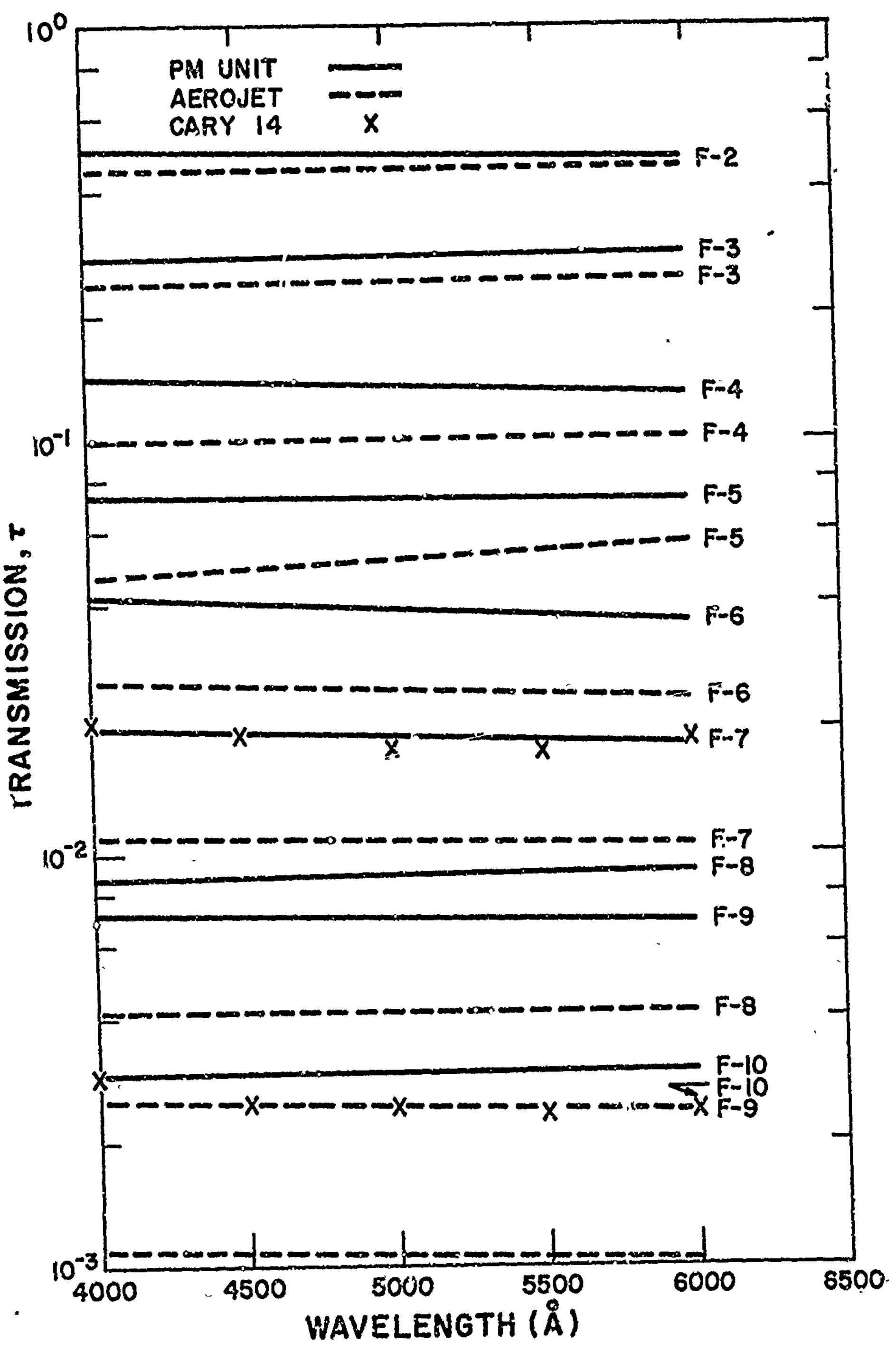


Fig. II-24 Comparison of Aerojet Spectral Transmissions with those measured with the PM unit on the J216 Calibrator and on the Cary-14 spectrophotometer.

filters as measured (1) by Aerojet on the Beckman spectrophotometer, Model DK-2, (2) with the photomultiplier unit on the J216 calibrator, and (3) on the Cary-14 spectrophotometer for filters 7 and 10 only. The agreements between the photomultiplier and Cary-14 measured transmissions are excellent for filter 7 and generally within approximately 20% of each other for filter 10.

Figure II-24 shows general agreement with Aerojet with respect to the filters being neutral density over the wavelength region observed. Thus, one should be able to compare the GAF microdensitometer reading with the spectral measurements made on the J216 with the PM unit and on the Cary-14 spectrophotometer. Figure II-25 shows the microdensitometer traces obtained across a diameter of each J216 filter with the GAF microdensitometer. It is seen that, except for occasional decreases in density due to non-uniformities and/or pinholes, the density is generally quite uniform.

Figures II-26, II-27, II-28 are plots of filter transmissions obtained on the J216 with the PM unit as a function of the Aerojet filter transmission for the various apertures. The densities obtained with the GAF microdensitometer and Cary-14 spectrophotometer are also shown. It is seen that the agreement between the measurements is generally good. It is also seen that for filter 10 the Cary-14 agrees more closely with the measured value on the J216 than does the GAF microdensitometer.

If there were agreement with the Aerojet values not only is a slope of unity expected, but a one-to-one relationship between the absolute value of the transmission. The line for agreement is indicated in figures II-26, II-27, II-28. Also, if the densities are uniform across the filter, the transmission values should be independent of aperture. Observation of the figures shows this not to be the case.

In order to establish that the observed large discrepancies and scatter in transmission observed with aperture 9 are possible when the dimension of the pinholes approaches the dimension of the aperture, the scanning aperture of the GAF microdensitometer was reduced to approximate the diameter of aperture 9, i.e., 10μ. Filters 4, 8, 9, and 10 were searched for pinholes with a dimension approximately that of aperture 9, i.e., 10μ in

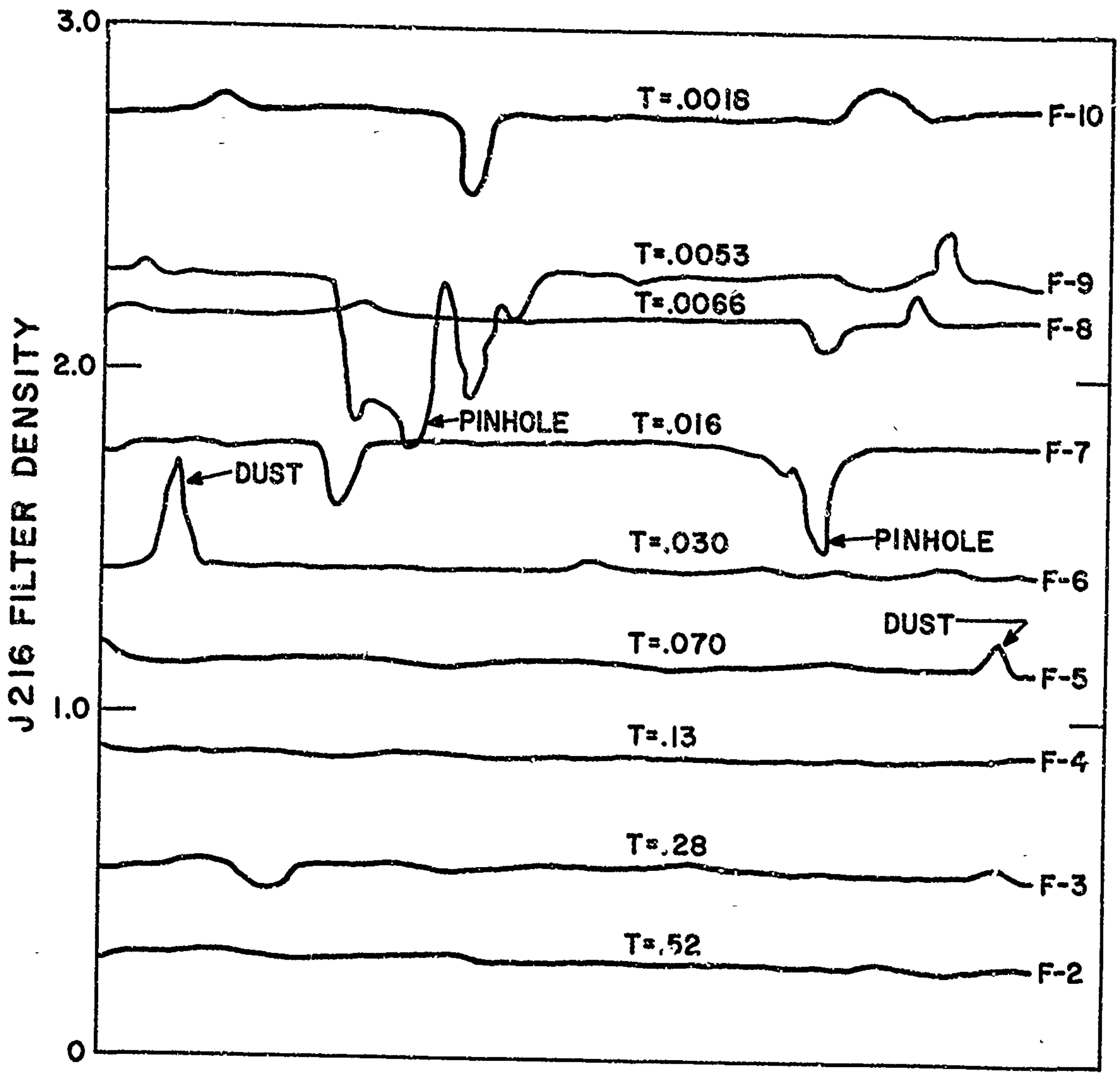


Fig. II-25 GAF Microdensitometer traces across surfaces of J216 filters.

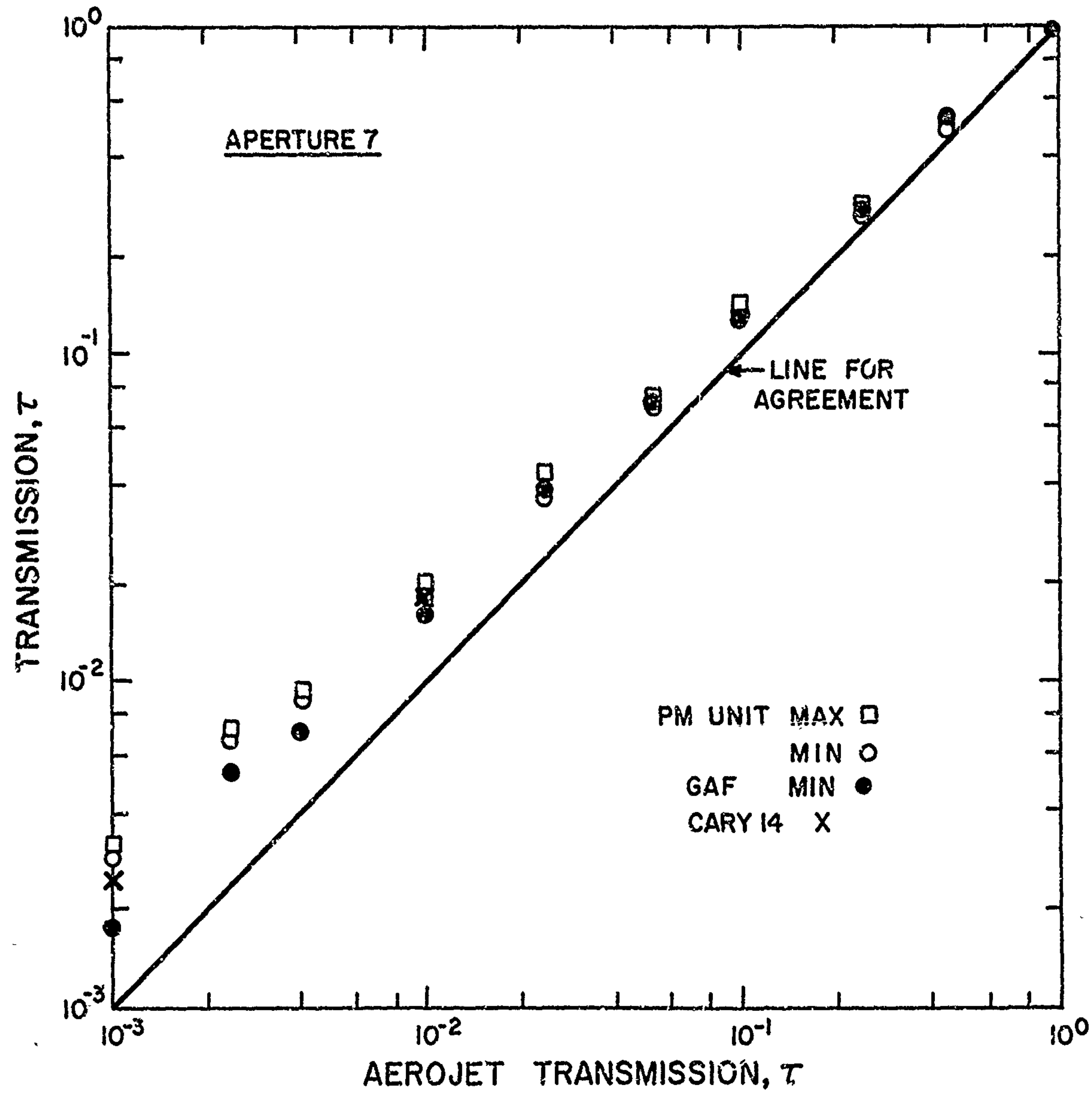


Fig. II-26 Comparison of J216 filter transmissions as measured with the PM unit, on the J216 calibrator to the GAF Microdensitometer, and the Cary-14 Spectrophotometer with the Aerojet Published Filter Transmissions. (Aperture 7).

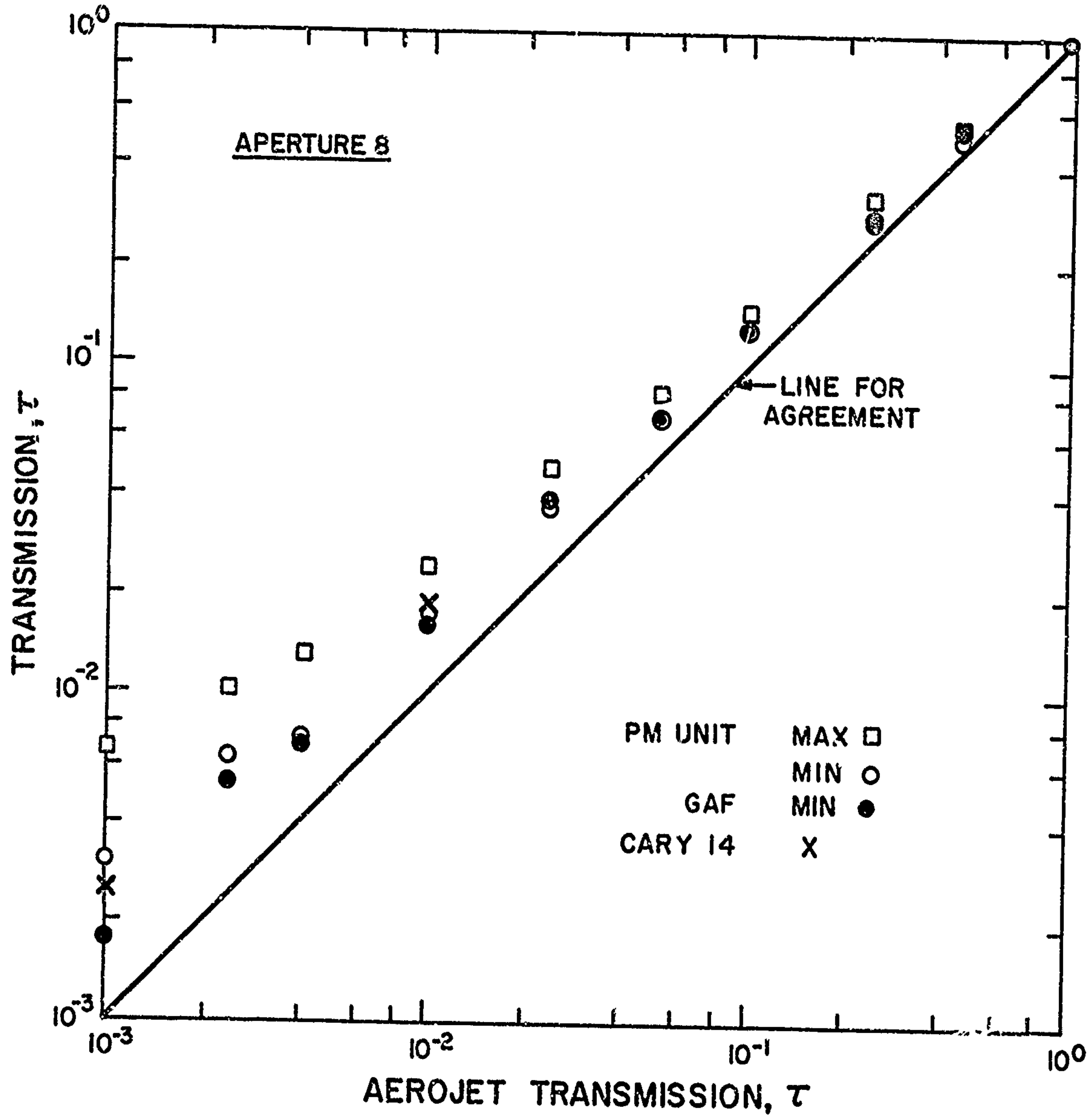


Fig. II-27 Comparison of J216 filter transmissions as measured with the PM unit, on the J216 calibrator, the GAF Microdensitometer, and the Cary-14 Spectrophotometer with the Aerojet Published Filter Transmissions. (Aperture 8).

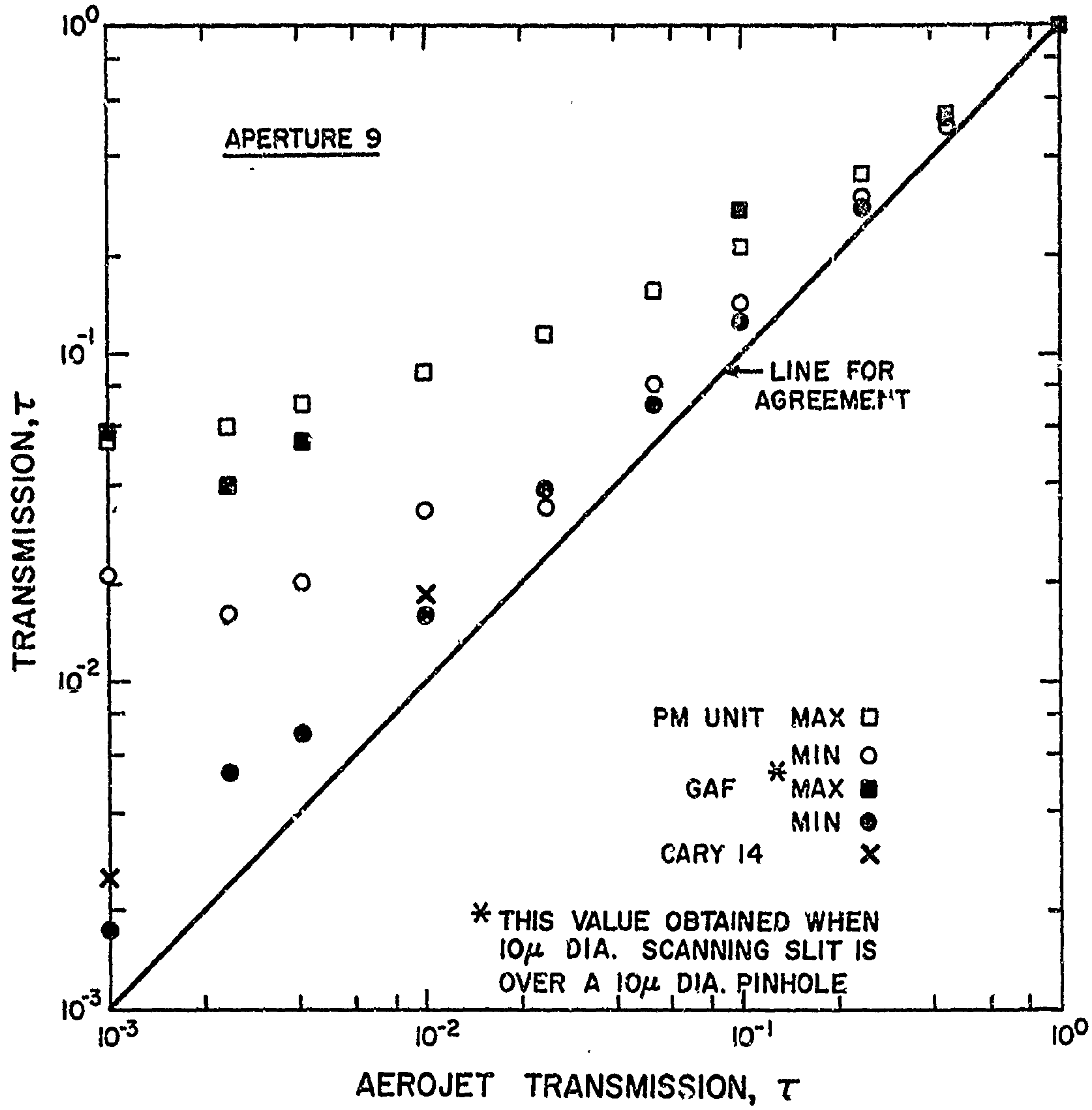


Fig. II-28 Comparison of J216 filter transmissions as measured with the PM Unit on the J216 calibrator, the GAF Microdensitometer, and the Cary-14 Spectrophotometer with the Aerojet Published Filter Transmissions. Shown also are the filter transmissions obtained on the GAF Microdensitometer with a scanning slit approximating the diameter of Aperture-9, i.e. 10μ, when over a pinhole of the same dimensions (See figure II-29). This was done to simulate the filter behavior in the J216 calibrator.

diameter and the densities measured when the aperture was outside and inside the pinhole to see if the same effects observed on the J216 could be produced. Because the pinholes were so small, the microdensitometer was operated manually so as not to degrade the data by producing rise times to which the instruments and the recorder could not respond. Figure II-29 shows the results of the microdensitometer traces thus produced. The values obtained are plotted on figure II-28, the data for aperture 9. They compare quite well with the maximum values obtained on the J216 calibrator with the PM unit.

Absolute Calibration of J216 Calibrator

It was indicated above that, except for the filter transmissions and the calculation of the irradiance for the S-11 channel of the R-71 for filter 10, the irradiance calculations and calibrations performed by Aerojet were apparently correct. To check the irradiance as observed in the J216 calibrator system, the photomultiplier unit was calibrated on a bench which contained a minimum of optical components.

The calibrator system study recently completed (refer to Task 4.0 under the -865 contract) indicated the need for such a primary standard irradiance unit. It was proposed that this unit consist simply of a source and apertures. A schematic of the unit is shown in figure II- 30. A prototype of this unit was constructed for the purpose of calibrating the PM unit. The calculation of the spectral irradiance is simply given by

$$H_\lambda = \frac{E_\lambda \quad N_\lambda \quad A_{ap}}{f^2}$$

where E_λ is the tungsten lamp emissivity, N_λ is the tungsten lamp radiance, A_{ap} is the area of the aperture and f is the distance between the aperture and the detector, the photomultiplier unit. The calculations were performed for the PM unit with an interference filter with center band wavelength at 5000 Å, the same filter used to check the J216 calibrators (see figure II-10).

The irradiances determined from the PM unit currents after calibration of the unit on the prototype of the AERL Primary Standard Irradiance

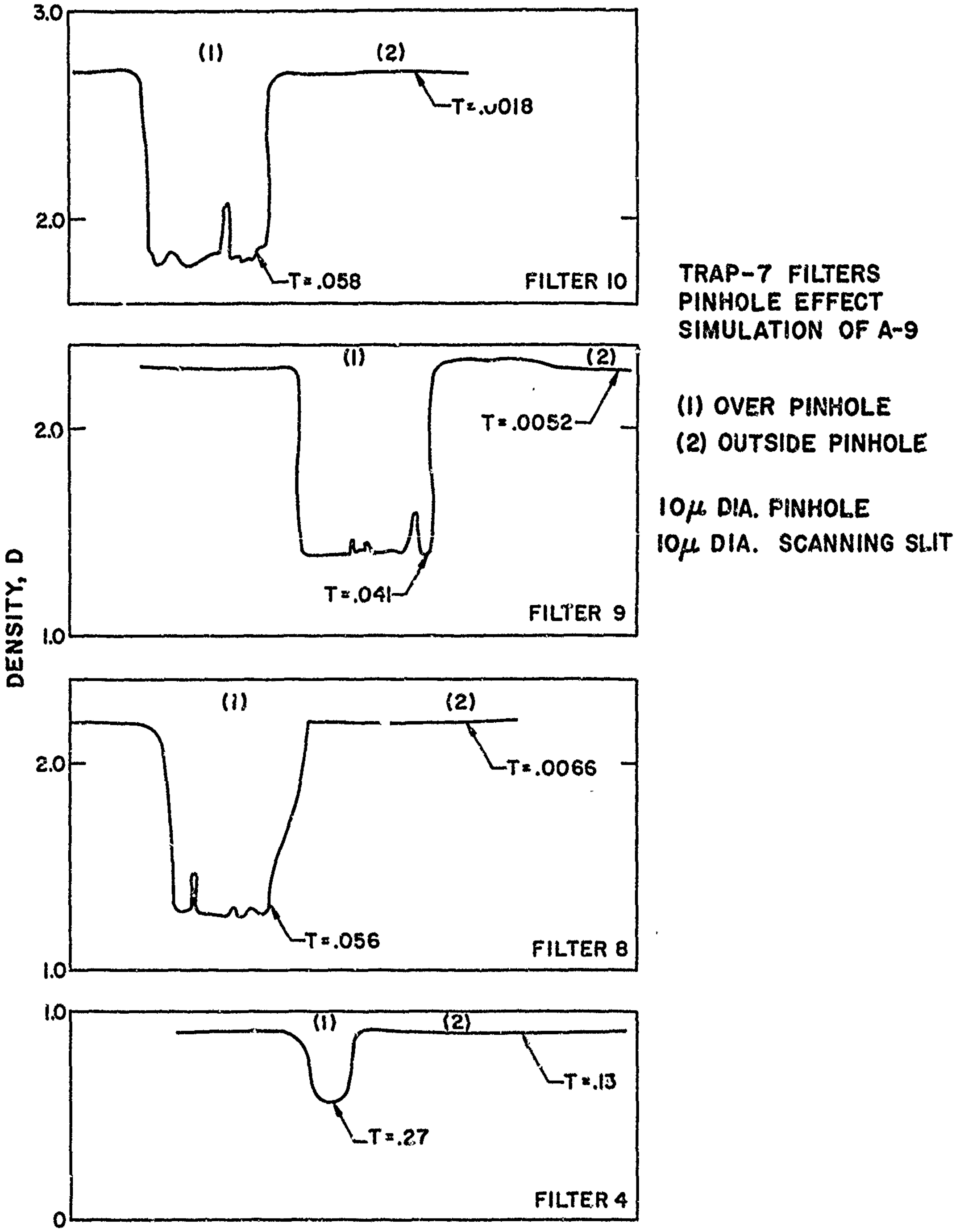


Fig. II-29 GAF Microdensitometer Traces of J216 Filters in the region with 10μ diameter pinhole.

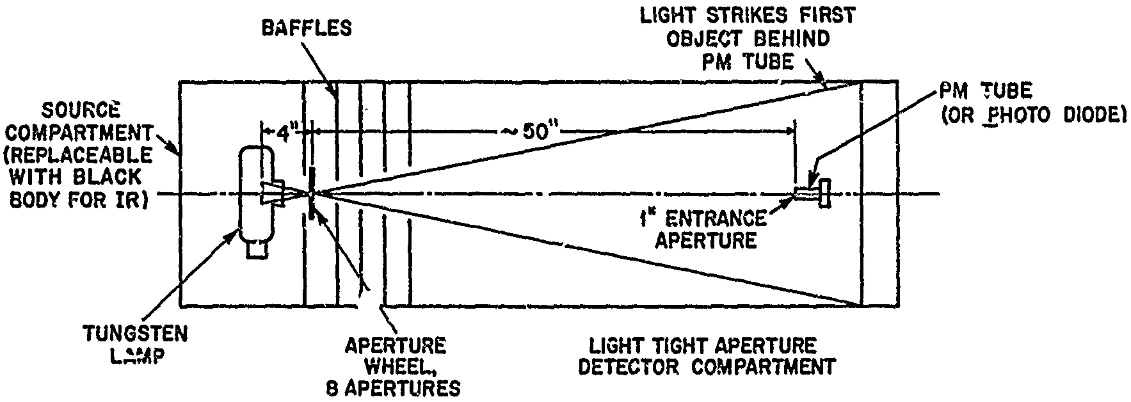


Fig. II-30 Schematic of AERL primary standard irradiance unit used for calibrating PM unit.

ur are shown as the black points in figure II-10 . It is seen that the ca. bration of the J216 calibrator as determined by the Aerojet is in agreement with the values determined by the calibrated PM unit.

Conclusions and Recommendation

The above discussion has shown that position of uniform filters in the optical system is not critical. It also confirms that whereas Kodak Wratten gelatin filters have extreme density uniformity over their surface. Inconel filters can have present in their surfaces, holes and inhomogeneities.

The effect of inhomogeneous filters placed close to the focus, resulting in the production of a non-uniform image, very likely accounts for one of the reasons for the differences between filter transmissions in the J216 and the measured values reported by Aerojet.

The difference in internal reflection and the type of density measured in the transmission measuring system (Beckman) and the J216 calibrator do not xplain the observed data and are not considered as a significant contributing cause of the filter transmission differences.

The fact that the Cary-14 and the GAF microdensitometer measure transmission values which generally agree with the values obtained on the J216 calibrator with the PM unit indicates that the Aerojet measurements were either performed incorrectly, or at sometime between the process of coating the filter and placing them in the J216, the coating physical characteristics changed. In discussing this latter reason with various people familiar with coating filters, it was indicated that a 1% change in transmission over a period of 10 to 12 months is considered reasonable. Therefore it strongly suggests that the other of the causes of the observed transmission differences is attributable to incorrect measurement of the filter transmissions.

In view of the above discussion, the following statements can be made; (1) Filter transmission is the presence of pinholes in the Inconel coatings of the order of the smallest aperture diameter and probably incorrect measurement of the transmissions; (3) Scatter produced at aperture 9 results from variation of the filters and aperture positions with respect to each other; (4) Aerojet calculations for calibrating the J216 are correct except for the

filter transmissions and the average spectral irradiance calculation for the R-71, S-11 surface, filter 10; (5) Aerojet apertures areas are approximately correct.

On the basis of the above results, to produce predictable results for the J216, modification or correction must be made to the filters or the filter wheel.

The alternatives are: (1) Replace the filters in the present wheel with more uniform filters; (2) Provide an arrangement for the collimation of the beam prior to focusing the tungsten ribbon, and place filters in this location; (3) to provide a very nearly uniform image, move the filters to a location close to the spherical mirror.

As an alternative to modifying or correcting the filters or the filter wheel, J216 behavior predictability can be attained by eliminating the filter wheel and obtaining the irradiance range of the J216 by using apertures alone and varying the temperature of the tungsten ribbon.

Figure II-31 is a plot of the irradiance range covered by the J216 calibrator at 5000 Å. The abscissa is the aperture diameter required to produce the same irradiance as each of the filters. Table II- 6 shows the black body temperatures required to produce a filter factor change in irradiance, approximately 2. By choosing aperture diameters corresponding to filter aperture combination 7-1, 7-3, 7-5, 8-1, 8-3, 8-5, 9-1 and decreasing the temperature to 1600°K, the range of the J216 can be duplicated. The number of points would be reduced.

Replacement of the filters, if adequate uniformity can be attained, is clearly the simplest approach.

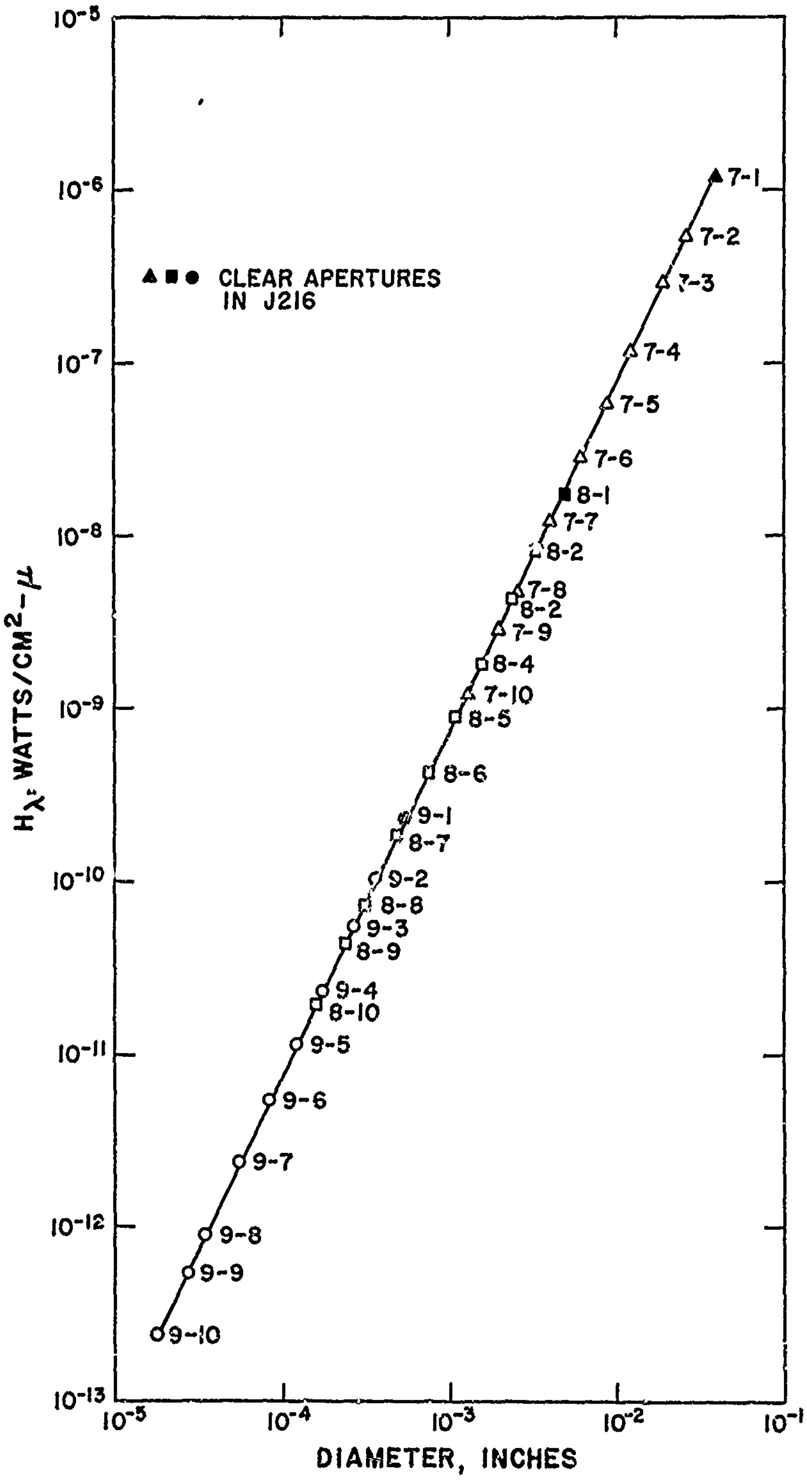


Fig. II-31 J216 Calibrator irradiance range, λ 5000 Å.

TABLE II-6

BLACK BODY TEMPERATURES CORRESPONDING APPROXIMATELY TO J216 FILTER CHANGES IN IRRADIANCE

J216 Filter	Black Body Temperature °K	Spectral Irradiance, W/cm^2-Ster-cm
1	*2600	5.98×10^4
2	2460	3.18×10^4
3	2320	1.57×10^4
4	2200	8.01×10^3
5	2080	3.8×10^3
6	1980	1.9×10^3
7	1900	1.02×10^3
8	1800	4.3×10^2
9	1700	1.7×10^2
10	1600	6.0×10^1

*Black body temperature corresponding to the J216 calibrator tungsten lamp at 35 amps.

INITIAL CONSIDERATION OF CALIBRATION PRECISION FOR TRAP-7 INSTRUMENTS

Introduction

Equations have been developed for determining the precision of the calibration of downrange 'nstruments assuming a normal frequency distribution. They are discuss. in this progress report under Task 3.0 of the -865 contract.* In the sections given below, these equations are applied to a number of calibrations of various TRAP-7 instruments performed on the J216 calibrator.

The TRAP-7 instruments are of two types: (1) radiometric-optical and (2) photo-optical. The radiometric-optical instrument analyzed in this report is the R-71 photometer consisting of an S-11 detector and an S-20 detector. The photo-optical instruments analyzed are: (1) the Barnes UV cinespectrograph, and (2) the High Speed camera.

About five calibration samples were analyzed for each of the photo-optical instruments, while for the R-71 photometer approximately 13 calibration samples were analyzed for each of several aperture-filter combinations of the J216 calibrator. Equation numbers shown in the ensuing text such as "equation (16)"[a] are those in the section referred to above which appear under Task 3 of -865.

Application of Statistical Analysis to TRAP-7 Instruments

Barnes UV Cinespectrograph

The fractional standard deviation in irradiance, σ_{H_f} for spectral cameras is given by equation (16)[a] as:

$$\sigma_{H_f} = \frac{2.3}{\gamma} \sigma_D, \qquad (1)$$

where γ is the logarithmic slope of the D-log E curve and σ_D is the absolute standard deviation in the density, D. Implicit in the variation of the density for a number of samples is the variation in γ. A value of 1.5 is assumed for γ, as was obtained from one of the mission films. At γ = 5000 Å, equation (1) then becomes:

$$\sigma_{H_f} = 1.5\sigma_D. \qquad (2)$$

*The title of the appropriate section is "An Approach for Estimating the Precision of Calibration of Downrange Instruments," and will be designated as Reference[a] for the remainder of this discussion.

Figure II-32 is a plot of the density as a function of wavelength for five calibrations of the Barnes UV cinespectrograph obtained on the TRAP-7 J216 calibrator with aperture 6, filter 1. While they appear on the same plot, there are differences in emulsion number and framing rate. The pertinent data required for determining σ_{H_f}, and the values of σ_{H_f}, are shown in table II-7 a number of wavelengths. The number of samples is too small for a confident indication of precision; however, it is felt that the precision estimated here is indicative of the magnitude of the precision expected when the number of samples increases.

The general precision of the spectral calibrations is a fractional standard deviation, σ_{H_f}, of $\pm .20$ with a maximum value of $\pm .31$. There is some indication that emulsion number affects the precision, in that the fractional standard deviation for emulsion number 87 - 23 is generally $\pm .02$, approximately a factor of ten improvement. It is recognized that only two samples have provided this result and its validity must await further sampling. Also at shorter wavelengths and/or small irradiances the precision of the calibrations improves. For example, at $\lambda = 3800$ Å and a framing rate of 15 frames per second, $\sigma_{H_f} = \pm .0542$ while at $\lambda = 6000$ Å, $\sigma_{H_f} = \pm .194$. The same trend appears to be occurring with the data for a framing rate of 10 frames per second.

R-71 Radiometer

The fractional standard deviation for radiometers is given by equation (10)[a] as:

$$\sigma_{H_f} = \sigma_{V_f} \tag{3}$$

where σ_{V_f} is the fractional standard deviation of the voltage, V.

Figure II-33 indicates the number of samples (and their spread) used in the statistical analysis. It shows approximately 13 calibrations each for a number of J216 calibrator aperture-filter combinations and gain channels of the R-71, detector 1 (S-11 surface) and R-71, detector 2 (S-20 surface). The pertinent data required for determining σ_{H_f}, and the values of σ_{H_f}, are shown in table II-8 for the data shown in figure II-33. The number of

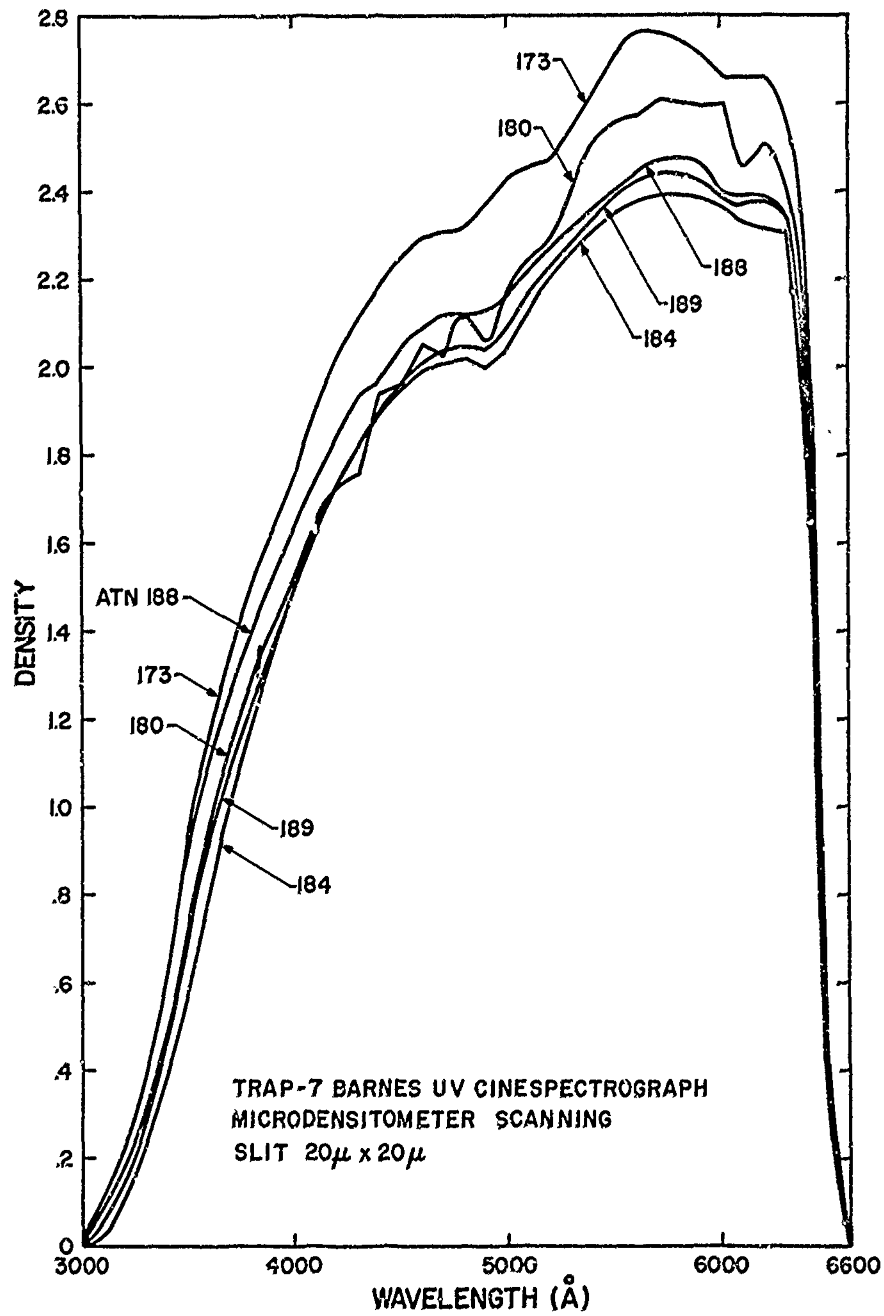


Fig. II-32 Barnes UV Cinespectrograph J216 calibration data, Aperture-6, Filter 1, from calibrations made after a group of TRAP-7 missions. (The 3-digit numbers are internal Avco Test Numbers.) Shown is the film density as a function of wavelength.

TABLE II-7

PRECISION AND STATISTICAL DATA USED FOR ESTIMATING THE PRECISION OF J216 CALIBRATION OF THE BARNES UV CINESPECTROGRAPH FOR A GROUP OF TRAP-7 MISSION CALIBRATIONS

INSTRUMENT DATA		STATISTICAL DATA													STATISTICAL ANALYSIS RESULTS		
Instrument	Spectral Range	Film Type	Processing	Framing Rate	J216 Aperture No.	J216 Filter No.	λ	Emulsion No.	No. of Samples	ATN 173	ATN 180	ATN 184	ATN 188	ATN 189	Average Density, $\bar{D}$	$\bar{H}_\lambda$	σ_{H_f}
	microns			frames per sec			Å			film density	film density	film density	film density	film density		$\frac{\text{joules}}{\text{cm}^2\text{-}\mu}$	
Barnes 18-134 Cinespectrograph	.30μ-.60μ	4X	Versamat	15	6	1	3600	89-121 87-23	1 2 *3		1.28 1.28	1.21 1.21		1.23 1.23	1.22 1.24	5.51×10^{-10}	2.12×10^{-2} 5.42×10^{-2}
							4000	89-121 87-23	1 2 *3		1.51 1.51	1.51 1.51		1.49 1.49	1.50 1.50	6.77×10^{-10}	2.12×10^{-2} 1.83×10^{-2}
							4500	89-121 87-23	1 2 *3		1.96 1.96	1.96 1.96		1.95 1.95	1.96 1.96	1.67×10^{-9}	1.06×10^{-2} 1.06×10^{-2}
							5000	89-121 87-23	1 2 *3		2.17 2.17	2.04 2.04		2.16 2.16	2.10 2.12	3.29×10^{-9}	1.27×10^{-1} 1.09×10^{-1}
							5500	89-121 87-23	1 2 *3		2.57 2.57	2.35 2.35		2.38 2.38	2.36 2.43	5.33×10^{-9}	3.36×10^{-2} 1.79×10^{-1}
							6000	89-121 87-23	1 2 *3		2.60 2.60	2.37 2.37		2.39 2.39	2.38 2.45	7.08×10^{-9}	2.12×10^{-2} 1.94×10^{-1}
		4X	Versamat	10	6	1	3800	89-121 87-[illegible]	1 1 *2	1.52 1.52			1.43 1.43		1.47	8.26×10^{-10}	9.50×10^{-2}
							4000	89-121 87-23	1 1 *2	1.76 1.76			1.66 1.66		1.71	1.02×10^{-9}	1.06×10^{-1}
							4500	89-121 87-23	1 1 *2	2.25 2.25			2.05 2.05		2.1[illegible]	2.50×10^{-9}	2.12×10^{-1}
							5000	89-121 87-23	1 1 *2	2.43 2.43			2.16 2.16		2.29	4.93×10^{-9}	2.86×10^{-1}
							5500	89-121 87-23	1 1 *2	2.70 2.70			2.41 2.41		2.53	7.99×10^{-9}	3.08×10^{-1}
							6000	89-121 87-23	1 1 *2	2.66 2.66			2.45 2.45		2.55	1.06×10^{-8}	2.22×10^{-1}

*Total number of samples

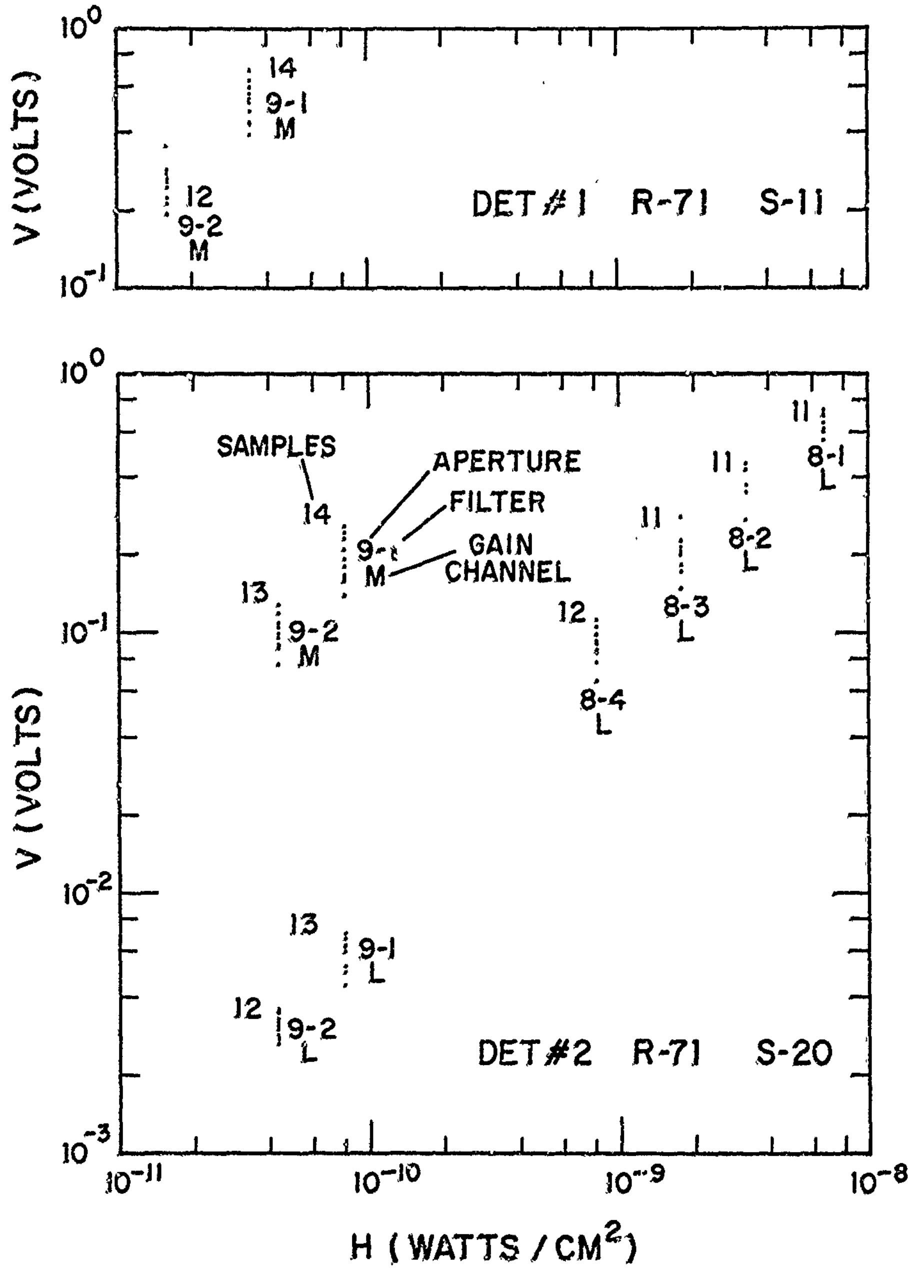


Fig. II-33 R-71 radiometer, J216 calibration data, for a number of aperture-filter combinations, from a group of TRAP-7 mission calibrations. The number of samples and the J216 aperture-filter combination are indicated. Shown is the radiometer output voltage as a function of irradiance.

TABLE II-8

PRECISION AND STATISTICAL DATA USED FOR ESTIMATING THE PRECISION OF J216 CALIBRATION OF THE R-71 RADIOMETER FOR A GROUP OF TRAP-7 MISSION CALIBRATIONS

INSTRUMENT DATA		STATISTICAL DATA																				STATISTICAL ANALYSIS RESULTS		
Instrument	Spectral Range	J216 Aperture No.	J216 [illegible] No.	Radiometer Channel	No. of Samples	[illegible]	Special [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	*[illegible]	[illegible]	[illegible]	[illegible]	*[illegible]	[illegible]	[illegible]	[illegible]	Average Volts, $\bar{V}$	σ	σ_{d}
	microns					volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	volts	watts/m²	
R-71 Radiometer Detector #1 (5-13)	.403μ-.504μ	9	1	Med	5	4.2x10⁻¹	[illegible]	[illegible]	5.2x10⁻¹	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.38x10⁻¹	[illegible]	[illegible]
		9	2		15	2.1x10⁻¹	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.65x10⁻¹	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.70x10⁻¹	[illegible]	1.69x10⁻¹
R-71 Radiometer Detector #2 (5-20)	.660μ-.780μ	9	1	Med	15	1.4x10⁻¹	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.45x10⁻¹	2.00x10⁻¹	[illegible]	[illegible]
				Low	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.6x10⁻³	[illegible]	[illegible]	[illegible]	[illegible]
		9	2	Med	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.67x10⁻¹
				Low	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.50x10⁻¹
		[illegible]	1	Low	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.0x10⁻¹	[illegible]	6.60x10⁻¹	[illegible]	9.0x10⁻²
		[illegible]	2		15	2.8x10⁻¹	[illegible]	8.65x10⁻¹	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.0x10⁻¹	[illegible]	3.92x10⁻¹	[illegible]	[illegible]
		[illegible]	3		15	[illegible]	[illegible]	[illegible]	[illegible]	2.22x10⁻¹	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.6x10⁻¹	2.5x10⁻¹	2.15x10⁻¹	[illegible]	[illegible]
		[illegible]	4		15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.36x10⁻¹

Note: * Consecutive calibrations [illegible]
** [illegible] saturated
[illegible] offset corrections applied to [illegible]

samples used are enough to provide a precision which is representative of the precision to be expected in radiometer calibration.

The general precision of radiometer calibration is a fractional standard deviation, σ_{H_f}, of $\pm .15$. The table indicates that this precision is preserved irrespective of irradiance, at least for the values used in the analysis.

High Speed Camera

The fractional standard deviation in irradiance, σ_{H_f}, for cine cameras is given by equation (26)[a] as:

$$\sigma_{H_f} = \frac{1}{A} \sigma_\beta \tag{4}$$

for the spot densitometer method used at AERL in measuring image growth. Here σ is the absolute standard deviation of an integral, β, where

$$\beta = \int_0^{R_I (H)} \tau_I (r)^r \, dr \tag{5}$$

and

$$\beta = A \ln H/H_o.$$

Here A is the local lgoarithmic slope and varies for different irradiance values as indicated in Reference[a]., and τ_I is the transmission of the positive, after the background transmission has been subtracted. The voltage output of the spot densitometer is proportional to β. The value of A for J216 aperture 9, filter 1, used for estimating σ_{H_f} for the high speed camera was obtained from Reference[a]. Equation (4) becomes:

$$\sigma_{H_f} = 3.10 \times 10^{+5} \sigma_\beta . \tag{7}$$

Figure II-34 shows microdensitometer traces of the positives of the images for five calibrations of the high speed camera obtained on the J216 calibrator with aperture 9, filter 1. While they appear on the same plot there are differences in emulsion number and framing rate. Shown also is the positive transmission, τ_I. It is this curve that is integrated in equation (5).

The pertinent data required for determining σ_{H_f}, and the values of σ_{H_f} for figure II-34 are shown in table II-9. Here, as for the cinespectrograph data, the number of samples is too small. However, it is felt that the precision estimated here is indicative of the magnitude of the precision expected when the number of samples increases. Table II-8 indicates a precision of the high speed camera calibration of a fractional standard deviation, σ_{H_f}, of ± 0.175.

Conclusions

Using equations previously derived[a] in which the irradiance is assumed to be precisely known, an estimate has been made of the precision of the calibration of TRAP-7 instruments using the J216 calibrator. Although the number of samples was small, the statistical analysis indicates a precision given by the fractional standard deviation in irradiance of between $\pm .15$ and $\pm .30$ for the TRAP-7 instruments, analyzed, with the most consistent precision occurring in the R-71 radiometer calibration. There are indications that there may be an effect of emulsion number on the precision in cinespectrograph calibration. More confidence in these conclusions must await an increase in the number of samples.

TABLE II-9

HIGH SPEED CAMERA FOR A GROUP OF TRAP-7 MISSION CALIBRATIONS

INSTRUMENT DATA		STATISTICAL DATA													STATISTICAL ANALYSIS RESULTS		
Instrument	Spectral Range	Film Type	Developing Process	Framing Rate	J216 Aperture No.	J216 Filter No.	Negative Emulsion No.	Positive Emulsion No.	No. Samples	ATN 170	ATN 172	ATN 173	ATN 174	ATN 168	$\bar{\beta}$	$\bar{H}$	σ_{H_f}
	microns			frames per sec						β, cm^2	β, cm^2	β, cm^2	β, cm^2	β, cm^2	cm^2	joules	
Milliken DBM 5A High Speed Cine	.427-.629	2475	Filmline	198	7	1	112-08	75-2	*2		5.03×10^{-6}	3.93×10^{-6}			4.48×10^{-6}	1.66×10^{-12}	2.40×10^{-1}
f/2.5 f_1= 100 mm							112-04	69-6 82-3	1 1 **4	5.14×10^{-6} 5.14×10^{-6}	5.03×10^{-6}	3.93×10^{-6}		4.39×10^{-6} 4.39×10^{-6}	4.62×10^{-6}	1.66×10^{-12} 1.66×10^{-12} 1.66×10^{-12}	[illegible]$.75\times10^{-1}$
		2475	Filmline	126	9	1	112-08	75-2	1				5.25×10^{-6}			2.60×10^{-12}	

* Number of positive samples
** Total number of samples

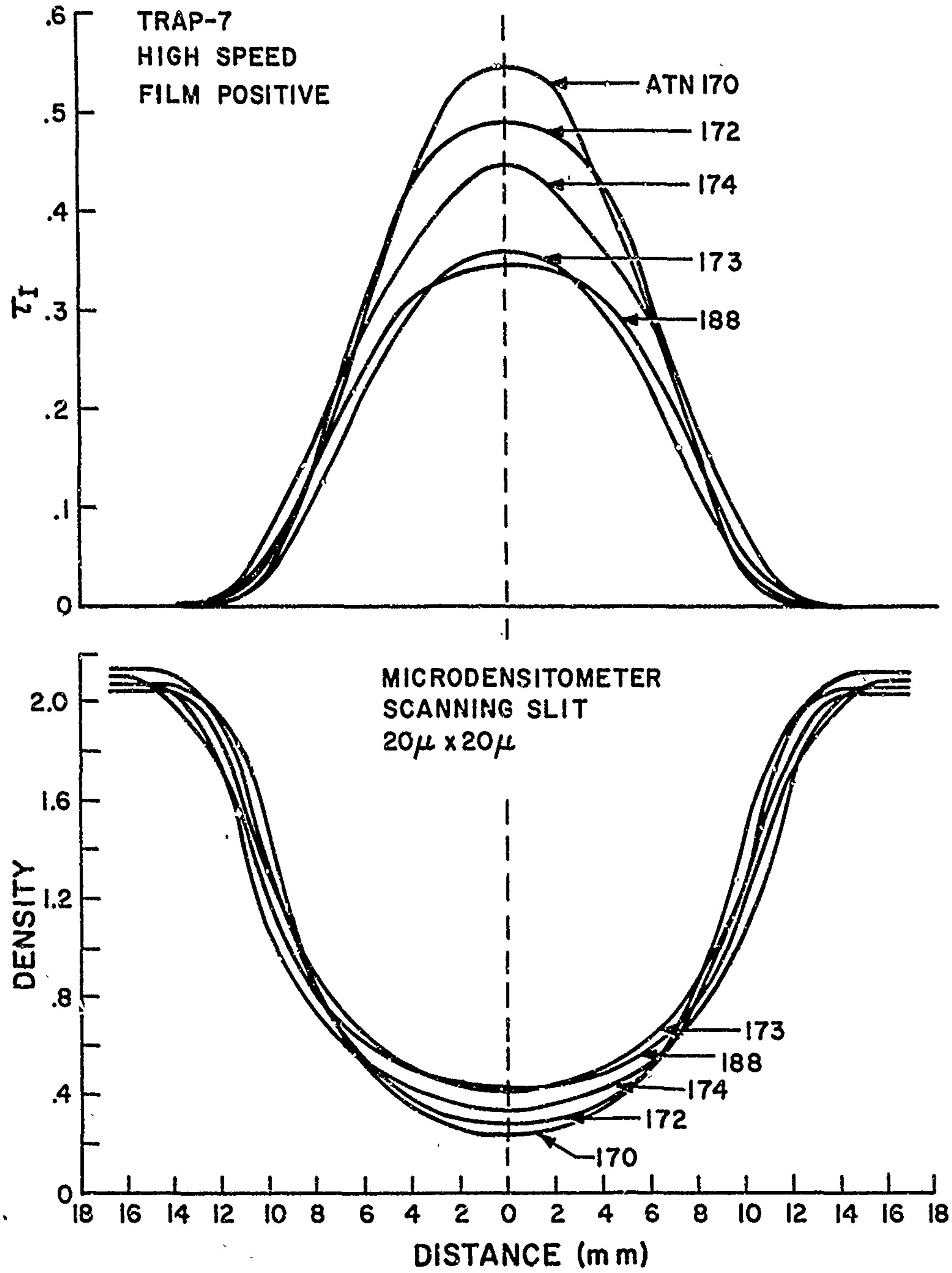


Fig. II-34 High Speed Camera, J216 calibration dr'ı, Aperture-9, Filter 1, for a group of TRAP-7 mission calibrations. Shown are microdensitometer traces of the positive images and the transmission variation across images after the background has been subtracted. The image transmission is the quantity to which the spot densitometer is sensitive.

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11 SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY SAMSO- Deputy for Ballistic Missile Re-entry Systems, AFSC, Norton Air Force Base, California

13 ABSTRACT

A narrative summary is given of the progress and status of six months' work performed by Avco Everett Research Laboratory for the Terminal Radiation Program (TRAP). The period covered is January 1, 1967 through June 30, 1967. Efforts are described for those tasks which can be discussed in an unclassified manner, and include program management, operations, instrumentation and maintenance, calibration and system studies. These tasks are discussed for the TRAP-6 and TRAP-7 re-entry monitoring aircraft and the TRAP-Transportable ground station. In addition, work pertaining to the upgrading of the TRAP-1 aircraft is described.

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KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
1. TRAP Program						
2. Re-entry monitoring						
3. Optical re-entry data						
4. Re-entry physics						
5. Optical data processing and reduction						
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